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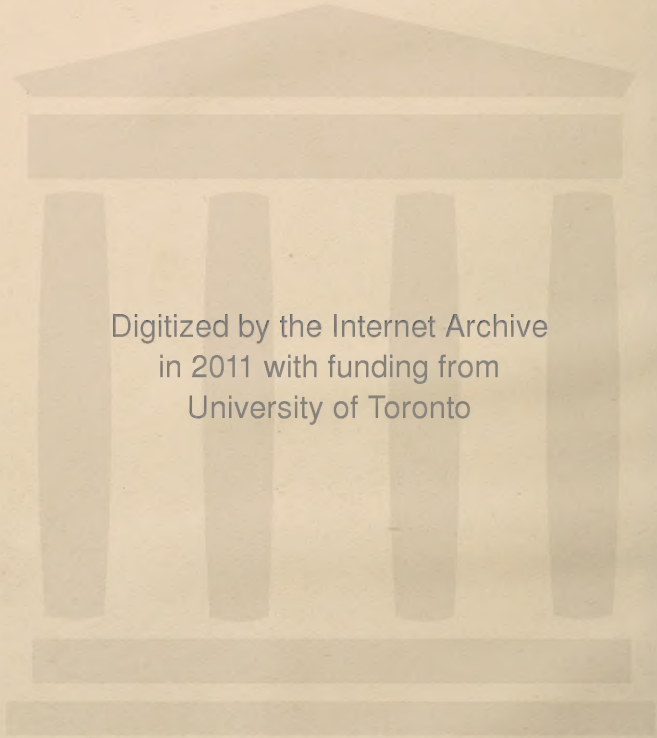

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THE CONCRETE INSTITUTE

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, ETC.

(FOUNDED 1908. *INCORPORATED* 1909).

TRANSACTIONS

AND

NOTES

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PREFACE.

The present volume of "Transactions and Notes," as well as Volume X., require a few words of special notice to the following effect:—That it was considered desirable as a wartime measure to print off the complete edition of the Papers instead of keeping the type standing; the locking up of type was inconvenient to printing firms during the war, and this also had to be taken into account. Consequently the value attaching to revision of Papers and also to consecutive pagination, only possible where type is kept standing, is lost under the other conditions.

Endeavours to supply an Index can only succeed by taking special measures, noted at the commencement of the Index at the end of this volume, and the indulgence of members is requested under these circumstances.

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NOTES.

On May 31st, 1918, the Institute had 824 Members, 75 Associate-Members, 13 Associates, 56 Students, 4 Special Subscribers and 9 Honorary Members.

DECEASED MEMBERS.

We regret to have to announce the following deaths dealing with the period up to the end of May, 1918:—

W. J. R. Barker, H.M. Office of Works.
W. E. Blake (now notified).
A. R. Debnam, Mount Pleasant, Plymouth.
S. Godden, Royal State Rlys., Southern Line, Siam.
J. P. Harvey, 112, Kilmorie Road, Forest Hill.
C. K. Keep.
C. L. Mais, Jamaica.
W. H. Martin, Holland.

Killed in Action and Died of Wounds.

Mr. D. T. H. Alderton.
2nd Lieutenant William Bell.
2nd Lieutenant H. Maguire.
Lieutenant H. R. Mais.
Mr. H. E. Metcalfe.
Captain W. H. Morton-Johnson.
2nd Lieutenant W. N. Olliff-Lee (1915, now recorded).
Lieutenant-Colonel B. J. Philpotts, D.S.O., R.E.
Mr. F. L. Rings.

ACCESSIONS TO THE LIBRARY.

We have to acknowledge with thanks the following donations to the Library, received up to the end of May, 1918:—

Allcock, H., "The Decimal System of Coinage and Weights and Measures."
American Concrete Institute, "Proceedings."
American Institute of Weights and Measures, Three Bulletins on Metric System.
Boswell, P. G. H., Prof. (Author), Several pamphlets on Sand.

Cambridge University Press, "Experimental Building Science," by J. Leask Manson, B.Sc.Eng.
Chapman and Hall, "Concrete—Plain and Reinforced," by Taylor and Thompson.
Concrete Publications, Ltd., "Concrete Cottages, Small Garages, etc."
Concrete Utilities Bureau, Six pamphlets on Concrete.
Department of Scientific and Industrial Research, "Science and Trade" (Pamphlet).
Elliott, Maclean & Co., "Reinforced Concrete Building Regulations, Sydney."
Etchells, E. Fiander, 34 pamphlets, "Science Abstracts," issued by Institution of Electrical Engineers, May, 1913—December, 1915.
Halsey, F. A. (Author), "The Metric System in Export trade."
London Master Builders' Association, "Handbook and Diary for 1918."
Marburg, Prof., U.S.A., Two pamphlets.
Marks, Percy L. (Author), "Principles of Architectural Design."
"Principles of Planning Buildings" (3rd Edition).
Portland Cement Association, Chicago, Several publications.
Wentworth-Sheilds, F. E., "British Standard Specification for sizes of broken stone and chippings."

The following Institutions forward their periodical publications to the Concrete Institute on an Exchange basis:—

American Society of Civil Engineers.
American Society of Mechanical Engineers.
The Architectural Association of London.
The Clerks of Works Association.
Department of Commerce, Washington, D.C.
Engineering School, Washington Barracks, D.C.
Engineering Society of Western Pennsylvania.
Institute of Metals.
Institution of Mechanical Engineers.
Institution of Mining Engineers.
Institution of Municipal and County Engineers.
Liverpool Engineering Society.
Northern Engineering Society, N.S.W.
Royal Institute of British Architects.
Royal Sanitary Institute.
Royal Society of Arts.

(*continued.*)

Society of Architects.
Society of Engineers.
Surveyors' Institution.

The following magazines are kindly forwarded on behalf of the proprietors:—

"Architect."
"Architect and Engineer of California."
"Builder."
"Canadian Engineer."
"Concrete and Constructional Engineering."
"Engineer."
"Engineering."
"Engineering News-Record."
"Ferro-Concrete."
"Gewapend Beton."
"Indented Bar Bulletin."
"Municipal Engineering."
"Surveyor."

Owing to the delayed publication of this volume we are able to introduce the following letters for the consideration of members of the Institute:—

Bruxelles, 50, rue de la Loi,
23 *avril*, 1920.

The Concrete Institute,
296, Vauxhall Bridge Road,
Westminster, S.W.1.

Messieurs,

En me référant à votre honorée lettre du 29 avril, 1919, j'ai l'honneur de vous annoncer que je vous adresse sous un pli séparé un exemplaire de mon AGENDA DU BETON ARME 1920. Je vous prie de bien vouloir examiner la possibilité de traduire cet ouvrage en Anglais; j'estime que les frais d'édition seraient couverts par les annonces et qu'un Concrete Pocket-Book serait accueilli par les ingénieurs et contractors brittaniques avec satisfaction; l'édition Française a un très grand succès en Belgique, France et Colonies; je reçois les commandes d'Egypte, Indochine, Maroc, Canada, Amérique, Portugal, Espagne, Italie.

Au plaisir de vous lire je vous présente, Messieurs, mes salutations les plus distinguées.

(Signed) V. Muzak.

63, Queen Victoria Street,
London, E.C.4,
17*th Feb.*, 1920.

Dangerous Structures.

Transactions, Vol. VII., pages 112-113.

The Secretary of the Concrete Institute.

Sir,

May I suggest that the term "foundation" be exclusively applied to the soil below any structure; and that the portion of the structure resting on the "foundation" be invariably known as the "founding" or the "footings."

I am, Sir,

Your obedient servant,

(Signed) E. A. W. Phillips.

Discussions, Contributions and Correspondence

With reference to some of the Papers read during the Session, 1916-17.

(For the Papers see Volume VIII.).

THE CONCRETE INSTITUTE:

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, Etc.

THE SEVENTIETH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall at Denison House, 296 Vauxhall Bridge Road, Westminster, S.W., on Thursday, December 21, 1916, at 5.30 p.m.,

MR. F. E. WENTWORTH-SHEILDS (President) in the Chair.

The following applicant for Associate-membership was elected :—

FRANCIS JOHN SALKELD, Runcorn.

PROFESSOR HENRY ADAMS then read a paper on " Pile driving and the supporting power of piles " (see Vol. VIII " Transactions ").

DISCUSSION

THE PRESIDENT (MR. WENTWORTH-SHEILDS), in opening the discussion, said that Professor Adams had got together a mass of information, facts, and theories which were likely to be of the very greatest interest and assistance in connection with the intricate and elusive problem of ascertaining the proper supporting power of piles. He asked all those present who had had practical experience of the matter to give the results of it.

MR. C. S. MEIK, M.Inst.C.E. (Member), commented upon the great difference between the ultimate loads that a pile would carry according to the various formulæ. Taking two piles driven to the same set, one driven into Thames ballast for 10 ft. and the other into 40 ft. of rather soft clay, using the same ram with equal height of drop. According to the formulæ they should both carry the same ultimate

load, but there was no doubt that if they were allowed to stand for two months it would be found that the pile in the clay would carry a greater load than the other one owing to the additional skin friction. A few years ago the late Mr. C. A. Harrison, M.I.C.E., of the North-Eastern Railway, noticed the importance of skin effect in driving piles for crane foundations. Piles which had a set of from 4 to 16 in. for the last ten blows of the ram absolutely refused to move after they had been standing for eight weeks until thirty minutes' continuous driving had taken place. This showed the influence of skin effect, and also the necessity of knowing the circumstances under which each of the formulæ given in the paper were framed. Weisbach's formula brought the weight of the pile into the calculation, which was misleading, for it would be found that by using formula (18) and that given in the note following the load carried by the pile could be materially increased by simply reducing the weight of the pile to a slight extent. It was for this reason that he regarded Trautwine's or Wellington's formula the safest for timber piles. As regards reinforced concrete piles, when he first used these, twelve years ago, none of the existing formulæ were applicable, and he accordingly decided to drive test piles of timber before driving the concrete piles. In this case the weight of the ram was 1 ton, the drop 9 ft., penetration $\frac{1}{3}$ in., the depth driven being 24 ft., of which 15 ft. were in the Thames ballast. Subsequently a concrete pile, driven to the same depth, the weight of the ram being 2 tons, the drop 4 ft. 6 in, twenty blows were necessary to drive it 1 in., the weight of the pile being 4 tons, compared with 1 ton in the case of the timber pile. According to Trautwine's formula, the timber pile should be equal to an ultimate load of 78 tons and the concrete pile 157 tons. The load ultimately placed on the concrete pile was 25 tons. The table in the paper showed what an enormous difference there was in the factors of safety allowed by the various formulæ, the variation being between 10 and 3. His experience was that for static loads, 3 was ample for a timber pile, whilst with a concrete pile 6 was necessary if existing formulæ were used. With a vibrating load

such as would come on the foundation of a heavy reciprocating engine then the factor must be higher.

MR. C. J. JACKAMAN, Assoc.M.Inst.C.E. (Member), said it would be useful if some definite number of blows could be assigned to the last few blows denoted in the formulæ by the letter *s*. He thought it was usually taken as ten. With regard to driving ferro-concrete piles, there were all sorts of surprises in store. He had had experience of two piles, one of which went down 18 in. and the other 9 ft. farther, both being driven into Thames ballast. That was not an isolated case. This effect would appear to be due to the hardening up of the surrounding ground.

MR. R. W. VAWDREY, B.A., Assoc.M.Inst.C.E. (Member), agreed as to the difficulty of choosing a formula, and complimented Professor Adams upon the useful work he had done in accumulating the mass of information on the subject that he had. The size of the dolly was discussed, but that must entirely depend on the length. It could only be treated as a strut between the ram and the pile. In speaking of the weight of the ram the author said that the energy of the falling ram was what counts. Was that correct? The energy was proportional to the square of the velocity, and the two instances given of a 5-cwt. ram falling 20 ft. and a 20-cwt. ram falling 5 ft. would have the same energy yet would not have the same effect. Had any members experience of reinforced concrete sheet piling? One of the troubles of this class of pile was that they were rather thin in one direction and had a tendency to bend momentarily under the blows of the ram. If there were any means of arriving at a minimum thickness for sheet piling, it would be useful to know it.

MR. CHARLES F. MARSH, M.Inst.C.E., etc. (Vice-President), said he could not see why there should be any difference between a formula for a timber pile and one for a concrete pile. The only difference was that the latter was a rather heavier pile and that, being stronger, it allowed of harder driving, but the chief advantage of the concrete pile was its durability and the greater strength of the unsupported length. Attention should be called to the danger of electrolytic action upon the reinforce-

ment of concrete piles, and care should be taken to prevent a leakage of electric current gaining access to the reinforcement. At Southampton a good deal of damage was done in this manner. Generally speaking, it did not seem that formulæ were very useful things in connection with piles, although something must be taken as a guide. None of the formulæ seemed to give absolutely reliable data. So many things had to be taken into consideration that he preferred to drive test piles to find out the resistance of the soil. It was necessary to drive sufficient test piles, however, owing to the possible variations in the soil in quite a small area.

MR. H. J. SHELBOURNE (Member) entirely agreed with the previous speaker that formulæ are practically useless. He cited two recent instances which he thought were fairly conclusive on the point. In the case of a chimney foundation, 35 ft. square, 100 fir and larch piles were driven, the piles having an average butt of $16\frac{1}{2}$ in. and an average top of 10 in. The first pile gave the desired set at about 5 ft. in the chalk and the adjacent pile gave similar results. After that, however, the results were entirely irregular, and it was an impossibility to apply formulæ to such circumstances. If they depended upon skin friction, the results varied very considerably. As regards the chalk level, in the case he had mentioned it varied 9 ft. in the small area of 35 ft. The second instance was a job on the other side of the river, on the Kentish marshes, where in an area of 2 acres 172 foundation piles were driven, the longest being 92 ft. and the shortest 36 ft. Four of the piles were over 60 ft. long, and the average was just over 40 ft. The last two blows on the first pile, which was 26 ft. long and $8\frac{1}{2}$ in. square, gave a total of 3 in. With another 20 ft. added the last two blows gave a total of $1\frac{3}{4}$ in.; but that not being thought satisfactory the pile was tested under a load of 10 tons. When 7 tons had been added a depression of $\frac{1}{4}$ in. occurred, and when the further 3 tons were added there was a depression of $3\frac{1}{2}$ in. Another 15-ft. length was then added, making the pile consist of three lengths, and when that had been completely driven the last six blows gave $2\frac{3}{4}$ in. The ram weighed 18 cwt., the drop was 6 ft., and a

friction winch was used for driving. On another pile, the total length of three pieces of which was 53 ft., the last 60 blows gave 16 in. It was then loaded with 10 tons, and after 24 hours the depression was only $\frac{1}{8}$ in., probably due to the compression of the head of the timber. In another case the pile was made up of two lengths, making a total of 40 ft., and the depression with a 10-ton load was $\frac{3}{8}$ in., but this did not increase when the load was left on for two days. The twentieth pile was about 19 ft. away from the fifth, yet the results did not by any means agree, and perhaps Professor Adams would give him some formula which could be depended upon in such circumstances. As to sheet piling, he had had a good deal of experience with timber and some with ferro-concrete, but had never had any trouble with either. As to the size and shape of the dolly mentioned by the author as 9 in. square and of oak, he saw no object in having the lower end of it hooped square, and it was much more expensive than the usual hooped circular dolly. In driving timber piles he did not like a steam hammer at all. The steam and water were liable to soften the head of the pile, and it was necessary occasionally to cut the head off and rehoop it, whereas a drop hammer worked by a friction winch did not give that result. The manner in which he tested piles was to apply eight blows to the inch with a 25-cwt. ram falling 6 ft. The weight of the ram should never be less than the weight of the pile, and an increase within reasonable limits was all to the good. At the same time, he never used a heavier ram than he could help, because as a contractor the heavier the plant that had to be moved the less the profit on the job.

MR. A. STEWART BUCKLE (Member), speaking on the question of the minimum size of sheet piling, said he was now connected with a Government factory where there were about eight miles of waterway, and it had hitherto been the practice to use 9×3 in. timber sheet piles to support the sides of the waterway. Owing to the cost of timber he had started to make concrete piles of the same dimensions, and he hoped they would last longer than the timber piles. They were certainly much cheaper. He had made them up to 11 ft. in length and had driven them through

5 ft. of Thames ballast. If he could only secure them in large enough quantities, he would also use them for maintenance work. Professor Adams had said that concrete piles might be driven after six weeks, but in one case in which he himself used them after two months the head broke. After three months, however, there was no breakage. In Ceylon, when he wanted some timber piles for temporary work he had been forced to use a native tree known as palmyra, which was similar to coco-nut. The inside was a pulp, but there was an outer crust of hard material about 1 in. thick, and these piles answered the purpose very well. He used hoop-iron off cement barrels as shoes, the end being cut to a chisel-point, and found it quite satisfactory. The piles were used for temporary work, but when they were withdrawn the hoop-iron was found to be in just as good condition as when the piles were first driven. The wood was taper, the big end being about 15 in. and the small end 5 in., and that fact possibly assisted in the ease of driving.

MR. EWART S. ANDREWS pointed out that in using any of these formulæ it should be remembered that the resistance of piles or the strength of piles can be regarded from three separate and distinct points of view. There was the penetrability, which was measured by the amount of the depression in the usual standard way; the second was the friction on the side of the pile; and thirdly, there was the strength of the pile, viewed merely as a strut or column. In computing the strength of a pile by any of these formulæ these three points of view must be kept in mind, and the strength of the pile must be regarded as the last of the three. Personally he preferred Wellington's formula. As to the doubts that had been cast upon the value of any formula, he would like to point out that without some formula they were just groping about in the dark. It was essential to have some formula, but an effort should be made to find out those that were reliable and to eliminate those that had been picked up in all sorts of places and based upon inaccurate reasoning. He could not agree with Mr. Meik that Weisbach's formula was unsound because the weight of the piles came in.

In dealing with this question in a book on Mechanics for students that he wrote a short time ago, he dealt with it from the theory of impact, and he got a formula which gave exactly the same result as the Wellington formula, if the weight of the tup were equal to the weight of the pile. Thus in his formula the weight of the pile came in, but he was not satisfied that the theory of impact was strictly applicable to pile-driving. The variables in the problem rendered it impossible to get an absolutely theoretical formula which would stand the test of practical experience. He believed the Wellington formula would be found to give as reliable a result as any from the penetration point of view.

PROFESSOR ADAMS, replying, said that the great object in regard to the weight and fall of the ram was in estimating the supporting power of the soil. His opinion was that the final set was the test of the soil. There was no need to look at the soil or to talk about what it consisted of geologically. The set of the pile took account of everything. His objection to Rankine's formula was that if you put a foundation on the surface of the ground it would not carry much, because there was no height above and around it to balance the weight, and he still maintained that to consider only the height of the soil round the base of a screw pile was an incomplete way of testing the supporting power of what was underneath. Mr. Jackaman had asked for a standard as to the number of blows that should be taken in considering the final set and suggested ten. His own practice had always been to give a maximum of 1 in. for the total of the last four blows, assuming the pile to have reached the required depth. Mr. Vawdrey mentioned the length of the dolly, but that depended upon the distance the pile had to be driven compared with the height of the pile engine. He had no experience of the effect of electric currents upon concrete piles, and therefore could give no information on the point. The recommendation to drive a test pile and find the actual resistance was quite good, and was what the Concrete Institute had been trying to get at by its inquiries, but nobody had ever done it satisfactorily, and there seemed little hope of it being done on

a large scale owing to the difficulty of making these tests. Mr. Shelbourne had criticized the 9-in. square dolly mentioned in the paper. That would about reach over the top of an ordinary round ring on the end of a pile, and that was the only reason. There was no particular advantage in having it square, and he would just as soon have it round. As to the time before reinforced concrete piles could be used, six to eight weeks was the minimum time under any possible circumstances, and naturally three months for seasoning was more desirable.

SEVENTY-FIRST ORDINARY GENERAL MEETING.

THURSDAY, JANUARY 25TH, 1917.

THE SEVENTY-FIRST ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held in the Lecture Hall, at Denison House, 296, Vauxhall Bridge Road, Westminster, London, S.W., on Thursday, January 25th, 1917, at 5.30 p.m., the President, Mr. F. E. Wentworth-Sheilds, M.Inst.C.E., being in the chair.

The PRESIDENT announced that there was one application for membership, viz., Mr. John George Jones, foreman of the Building Department of the United Tube Corporation, Ltd., Newport, and he was duly elected an Associate-Member.

Mr. C. R. PEERS then read his Paper, entitled:—

"THE CARE OF ANCIENT MONUMENTS."

(For this Paper see Volume VIII.)

DISCUSSION.

The PRESIDENT: "It is something of a departure to have a paper on the subject that has been dealt with by Mr. Peers. Whilst, however, it might be a little out of the rut of their usual papers the departure had been a successful one. In all departments of life there was a great deal to be learned from history and their own particular department was no exception. They were very much obliged to the author for telling them of the interesting work he had done."

Mr. W. G. PERKINS, District Surveyor for Holborn, said: "Unfortunately it is my function to condemn buildings which had become in the condition described rather than to preserve them, but Mr. Peers has confirmed what I said in my own paper some time ago as to builders in former times putting up a facing of superior masonry and filling in the interior of a wall with work of a most inferior description. I would like to have the author's opinion on the effect of the vibration caused by modern traffic where such buildings are in towns.

Probably some of them have already been subjected to this vibration, but if not they no doubt soon will be. I agree with the President that the paper is a departure from the usual practice, but it is a departure that has been amply justified, and I have much pleasure in proposing a hearty vote of thanks to Mr. Peers."

Mr. F. W. Troup, F.R.I.B.A., said: "When the Colchester restoration was begun some years ago I was very doubtful about the method that was adopted; but judging from the description we have been given of what had been done there was no question, but that the Office of Works had adopted the right course. Jedburgh also seemed to have been a very successful piece of work and gave promise of good things to come when the Office of Works took up other buildings. I second the vote of thanks with great pleasure."

Mr. Archibald Scott, A.R.I.B.A., remarked: "As a member of the Office of Works it is not for me to blame or praise the way in which these things were handled. I have never given very much attention to ancient monuments and the paper has consequently been all the greater delight to me. Everyone would agree that the matter was treated in a most sympathetic manner and what struck me at once in the paper was that the real root of the trouble was got at to begin with and there was no mere case of patching."

Mr. W. A. Forsyth, F.R.I.B.A., said: "We are very fortunate in having the Ancient Monuments Department, because for many years this country had been suffering from the want of it. Moreover, the Department was doing its work in the soundest possible way. I had been in hopes that Mr. Peers would have linked up his subject with the one more closely associated with the Institute by referring to the use of iron in buildings, because iron in ancient buildings was the cause of no end of trouble. It caused disintegration and endless damage which did not shew itself for many years. An example of this was the damage done by the iron rods, ties and bolts in St. Paul's Cathedral inserted by Sir Christopher Wren. Six months ago I was shewn in the dome an iron band immediately below the topmost course of masonry. This band was one inch thick, and the wet having got in and set up rust it had lifted the whole of the timber dome three quarters of an inch. I

would suggest, therefore, that reports of failures of buildings, ancient or modern, due to rust in ironwork, should be filed and should be made available to the members. Personally, I believe that far too much steel is being used in ferro-concrete. Coming back to the paper, Mr. Peers had left out one of the most important things in bonding, viz., to determine the points to be bonded. Bonding very frequently was done in a wholesale manner, but in my own practice I arrange that bonding that cannot be raked out shall be left. It should not be hacked out. The question of weak cores and ashlar facings is interminable and a most troublesome thing to contend with in repairing ancient buildings. It was interesting to observe how at Colchester the early ecclesiastical buildings carried on the Roman tradition of bonded tile courses. It is found in the eastern counties, but in few other places in England have I found any persistent bonding of rubble walls. It was, however, a practical necessity to do so because the walls were built in lime concrete with ashlar face. The ashlar face could not settle, because it was close jointed, but the rubble core, which was just dropped in anyhow, was liable to settle and the failures from this cause took place, in my opinion, in the early days and not in recent years. The cores settled and left the ashlar face, which was attacked by wet and disintegrated. What did Mr. Peers do with the steel rods in the new concrete core which he put to the walls at Jedburgh, a church which I happen to know very well indeed? Finally, with regard to pointing, this should never be finished with a metal trowel because it gets its hardness and unsatisfactory character from that. A piece of wood gives the best results."

Mr. Allan Graham said: "The paper ought to be of some interest to engineers as it certainly is to architects, for the reason that a great many engineers, unlike architects, are not sufficiently concerned with the æsthetic side of their work. From that point of view the Office of Works had, in recent years, made restoration a fine art. The contrast between the present day work and some of the early restorations was too well known to architects to need mention. St. Albans, for instance, had been dealt with in such a way that the whole character of the original structure had been lost. I much prefer the type of restoration at Dunblane Cathedral, carried out by Dr. Rowand Anderson, which preserved the historical character of the building as far as it was possible to do so, and this had been

the actuating spirit of the Office of Works for a good many years. In the course of a discussion some years ago at the R.I.B.A., there was a great passage of arms between Mr. Thackeray Turner and Mr. Peers; their views on restoration were entirely opposed. Mr. Peers was in favour of a real workmanlike restoration and his opponent favoured a fanciful one. When a monument is handed down to us with all its associations and history it is our duty to pass it on to posterity in the best possible condition of preservation in its original form and that was what the Office of Works was doing throughout the country."

Mr. W. J. H. Leverton: "I recall that some years ago there was considerable discussion as to whether the restoration of ancient buildings was not a subject for an engineer instead of an architect and a good many people at that time seemed to follow the engineering theory. Mr. Peers, however, has discarded the engineer entirely—and deservedly so, because there must be a thorough knowledge of ancient buildings, of the man who built them and of the architecture of the time, before the buildings could be restored. St. Alban's Abbey had been mentioned, and the work done by Sir Gilbert Scott was infinitely superior to that carried out later. When Scott was at work, a certain wall of no importance was pulled down, but inside were found little pieces of masonry, and it turned out that they were really portions of the ancient shrine of St. Alban. They were built up and bound together with wires and iron bands, and but for the archæological knowledge displayed by Scott these pieces of masonry would in all probability have been broken up to form concrete. The engineer certainly would not have appreciated their value, unless he had studied architecture. As to the point raised about the rusting of iron in old walls, we are frequently assured that there is not the slightest possibility of the steel in reinforcement rusting; but can we rest assured that this is the fact? If not, there would be a terrible awakening sooner or later."

Mr. Ewart S. Andrews remarked: "I am fully in accord with everything that has been said in favour of the Institute having a paper of this description, and speaking as an engineer I may add that I have thoroughly enjoyed it. I have very little knowledge of archæology or ancient architecture; but in going round old buildings I have been struck with the sympathetic treatment which is now being given and which does not seem to have been observed in the past.

It could frequently be seen in an old cathedral that architects had just added their bit in their own way without any consideration of the original style at all. As to the fears that seem to have been aroused by Mr. Forsyth's remarks upon the use of iron and the possible dangers from rust, I do not think that there are many reinforced concrete buildings which are likely to become national monuments."

Mr. ALEXANDER MCDOUGALL: "I think that three men are really required to deal with the restoration of ancient buildings, viz., an historical antiquary, a civil engineer and an architect. If the three men chosen had any brains at all then the combination would give all that was needed. From the paper it was evident that the Office of Works had gentlemen who knew how to deal with the restoration of our ancient monuments. As a Highlander I would like to refer to a very ancient building with which I am very familiar, as it belongs to the Chief of my own Clan—I refer to Donollie (the Fortification of the Steep Rock), near Oban in Argyllshire, built in the year 713. According to the annals it was originally built (685 A.D.) of wood surrounded by an earth mound and fosse. The walls are 9ft. 6in. thick and on one side there is a stairway in the wall itself. The mortar appears to be composed of local lime and volcanic nodules, because the whole district was undoubtedly a long time ago one huge volcanic mass. That mortar is extraordinarily hard and it would be very interesting if Mr. Peers could throw any light on the composition of such mortar as that used by Selbach, the Scoto-Irish ruler, in the year 713. Historians tell us that it was mixed with the blood of bullocks in the case of the Tower of London, but I do not see what good that did, unless perhaps the hairs of the animals were also included, and even then I do not know that it would be very beneficial."

The PRESIDENT said: "Mr. Leverton has had a gibe at the civil engineer, and being a civil engineer myself and an Irishman, I feel bound to stand up for my profession. Everyone agrees that the work of restoring ancient buildings should not be entrusted to a civil engineer any more than the building of the Forth Bridge should be entrusted to an architect. But reference had also been made to the work of Sir Gilbert Scott, at St. Alban's, and it might interest the members to know that when Sir Gilbert Scott was called in to advise as to the restoration of the spire of Salisbury Cathedral he told the Dean and Chapter that it was a work

that involved special knowledge of the stability of structures and recommended them to call in a civil engineer with whom he could consult. As I happen to be the son of the engineer who was called in, that fact is imprinted upon my memory. In a *general* way the work of restoration is not so complicated as in the case of Salisbury Cathedral, but such work must be entrusted to a man who is something of an antiquarian and something of an engineer as well as an architect; having heard the paper we might fairly say that these excellent qualities were combined in Mr. Peers. The paper was interesting not only because it spoke of the care of ancient monuments, but because it also told us what kind of building was favourable to long life and also what natural conditions were favourable or the reverse to longevity in structures. It was pointed out, for instance, that the great enemy of buildings was damp. I was very much impressed with my experiences in Egypt; above Cairo and near Assouan, the country is to all intents rainless and there is practically no deterioration of buildings. Houses in that district built of mud bricks seem as if they would never decay. In some of the quarries there are curious designs scratched on the stone, said by experts to have been done thousands of years ago, and these scratches can be seen as clearly as the day they were drawn. This shews how remarkably well buildings will stand in a dry climate. Mr. Peers said that the Roman mortar could hardly be improved upon, or even equalled, nowadays; I have heard that many times before, but I always took it with a grain of salt. I am not sure that we could not surpass in the way of mortar anything that the Romans did. As to the preservation of stone, I know that some years ago the Office of Works tried by experiments to produce a solution that would preserve the stone of the Houses of Parliament, and it was certainly curious, and perhaps a little disappointing, to hear that these had not been successful. The production of a solution which would render stone and concrete absolutely water-tight would be a most important discovery and would tend especially to prolong the life of reinforced structures. Damage to reinforced concrete buildings from rust is not likely to happen in any ordinarily dry situation. I say that, because there are so many instances of old concrete being cut to pieces, and pieces of iron, which were in a perfect state of preservation, being found embedded in it. On the other hand, there are occasional circumstances in which steel might decay in concrete and there is little doubt that the

cause of that decay is through damp getting through the concrete to the steel. If, therefore, we could discover some protective solution which would fill up the pores of the concrete and prevent damp getting in, there would be absolutely nothing to fear on that account. It always seems to me, looking at the matter as an engineer, that the use of ashlar facing is a great mistake. The engineer of one of the first large graving docks upon which I was engaged was, like most engineers of those days, no great believer in concrete. He used it for walls because it was cheap, but he faced the walls with brick. The brickwork, about 1½ bricks thick, was built up to a height of four feet and then the concrete was thrown in behind. When these walls were cut away later for some purpose or other it was found that in no case was there any sort of bond between the brickwork and the concrete and they gave no support to one another. This experience led me to the view that it is better to build the whole of the wall of the same material and at the same time. There is no doubt, in my mind, that as regards strength, stability and permanence, the use of ashlar facing with a rubble backing is a great mistake."

In answer to Mr. Perkins, who asked why there was no bonding, the PRESIDENT said it was simply because they did not adhere. The concrete appeared to have shrunk away from the brickwork.

Mr. PERKINS suggested that that might be due to the method of erection. Sir Arthur Blomfield built a church by means of walls of concrete faced with brickwork, and a very good bond was obtained.

Mr. PEERS: "I should like in the first place to express my appreciation of the manner in which the paper has been received. In answer to Mr. Perkins, on the question of vibration, that is a very difficult point; the remedy lies in the intrinsic strength of the masonry, as far as it can be maintained. Mr. Forsyth suggested that too much old mortar had been cut out at Colchester; it often happened that behind what appeared to be sound pointing there would be five or six inches of decayed mortar, and if one had to strengthen a building such as Colchester it would be no use leaving it like that. They must make up their minds to the loss of something and there have been occasions when I have had to cut out old pointing when I would have much preferred to leave it alone. Colchester was in a thoroughly bad condition; the wall tops there were treated with cement

mortar mixed with Pudlo. Certainly the majority of wall tops have to be treated in cement, although from above they probably look white, but that is one of the difficulties of dealing with this class of work. I am absolutely against the use of cement whenever I can avoid it. If I could get lime mortar which would stand on wall tops as well as cement, I would certainly use it. I agree that in a great many of the 12th century churches the failures occurred through weakness of construction, within a few hundred years of their being built, as, for example, a poor core with an ashlar facing. For strength, ashlar facing is not the best construction, but these buildings were not built from that point of view. The idea was that they should appear to be built of stone and where they were not they were faced over with plaster, and lines drawn to imitate stone. The steel rods at Jedburgh were put in with the idea of getting a better bond between the masses of concrete as the piers were gradually re-cored. Damp, of course, as was pointed out by the President, was responsible for most of the damage. I can fully endorse what he said as to the conditions in Egypt, where buildings which would not last here fifty years stood up for three thousand years; one temple had apparently massive ashlar walls, 18ft. to 20ft. thick, but filled with the chippings from dressing the stone and any rubbish they could find. All this had sunk together and the wall was for all practical purposes hollow. It was quite clear what an excellent thing the absence of rain was from this point of view."

A cordial vote of thanks was passed to Mr. Peers for his Paper.

The following written communication has been received with regard to Mr. Peers' Paper:—

From Mr. JOHN W. GRANT, A.M.C.I., A.F.P.W.Inst. (Lond.).

"Mr. Peers' Paper on the preservation of ancient monuments is one that is well worth having before us. Although he has given us some instances of old buildings giving way at their foundations, various causes may account for this, over which those who designed them had no control, and unforeseen by those now responsible for their maintenance.

"In regard to the care of ancient monuments, we are generally inclined to look to the superstructure for decay

in stonework and it is in this direction that most of our architects to-day are greatly interested to arrive at the best method to obtain suitable remedies to suit the atmospheric influences, whether in town or country, to preserve large and costly buildings which in a few years' duration shew signs of decay. It is pleasing to note, however, that some such experiments have been made with the view of arriving at the most effective treatment.

" It is a privilege to aid the preservation of old architectural landmarks with loving hands and restore the beauty of former generations."

EIGHTH ANNUAL GENERAL MEETING,

THURSDAY, NOVEMBER 22ND, 1917.

THE EIGHTH ANNUAL GÉNERAL MEETING of the CONCRETE INSTITUTE was held at Denison House, 296, Vauxhall Bridge Road, London, S.W., on Thursday, November 22nd, 1917, at 5.30 p.m., THE PRESIDENT, MR. F. E. WENTWORTH - SHEILDS, M.Inst.C.E., in the Chair.

THE PRESIDENT said it was with much regret that he had to announce that four members had been killed in action, viz., Lieut.-Col. B. J. Phillpotts, R.E., Capt. W. H. Morton-Johnson, Second-Lieut. William Bell and Mr. F. L. Rings. The Council had in every case expressed its sympathy with the relatives of these members and he was sure it was the wish of the members that that should have been done.

The following gentlemen were then elected as shewn :—

MEMBERS.

PERCY LYONS ABRAHAM, Colonial F.S.I., A.M.Am.Soc.C.E., Assistant Engineer and Surveyor, Permanent Way Department, Jamaica Government Railway.

FRANK CALVARD, Assoc.M.Inst.C.E., A.M.I.Mech.E., Engineering Assistant to Port of London Authority.

HERBERT WILLIAM CHARLES KEMPTON DYSON, Consulting Engineer.

VINAYAKRAO MADHAVRAO KOTASTHANE, Supervisor P.W.D., Office of Consulting Architect, Bombay.

FRANK STEPHEN REYNOLDS, M.S.A., Senior Assistant to Messrs. Hemmings and Berkeley, Architects and Civil Engineers, Hankow, China.

ALFRED GEORGE STEDMAN, Superintendent of Works Department at Messrs. Vickers, Ltd., Weybridge.

HENRY HERBERT WATKINS, Assoc.N.Z.Inst. of Architects, Engineer to the Auckland and Suburban Drainage Board, Auckland, N.Z.

ASSOCIATE MEMBERS.

CYRIL STANLEY CARTER, Captain R.E., Assoc.M.Inst.C.E., A.M.I.Mech.E.

ARTHUR E. HOBBS.

EDWARD KAYLOR, Lieut. R.E., formerly Civil Engineer with Messrs. Mouchel and Partners.

HUGH MONTGOMERY, M.R.San.I., Cape Town.

REUBEN STUBBS, Civil Engineer with The Trussed Concrete Steel Co.

ASSOCIATES.

FREDERICK HATCH.

HARRY MUNSON.

THE PRESIDENT then presented the Annual Report with a few remarks indicating the nature of its contents.

REPORT OF COUNCIL FOR 1916-17 SESSION.

The present Membership of the Concrete Institute and its alteration since the previous figures were given for the 1915-16 Session are shewn in the following table:—

NUMBER OF MEMBERS.

	End of Dec., 1915.	End of April, 1916.	Sept. 30th, 1917.
Members	880	877	835
Associate-Members ...	43	46	65
Associates	7	7	8
Students	57	57	57
Special Subscribers ...	5	5	4
Hon. Members	10	10	9
Total Membership ...	1,002	1,002	978

Of this total 374 reside in London and its environs, 316 reside in the provinces, and 288 abroad.

The decrease in Membership is attributable to the war; a considerable number of Members of the Institute are serving with the Forces.

The finances of the Institute are shewn by the accompanying Balance Sheet. In 1913, 1914, and 1915 there were deficits. A greater number of subscriptions are in arrear than in normal times. Rigid economy has been exercised and the printing of the Transactions has been delayed. Arrangements have been made to print part of the papers read in 1914-15, and those read in 1916-17 will be published without the Discussions, but on account of the high price of paper it is impossible to do more at present. The indulgence of Members is asked for in this respect. It is hoped that when peace is declared and business has resumed more of its normal course, the past growth of the Institute in Members and income will be resumed.

Owing to war conditions the number of General Meetings has been reduced, and the Educational Lectures and the Informal Meetings of Junior Members have again been abandoned for the Session. Such educational work will be resumed as soon as it is possible to do so.

The following is a list of Meetings during the Session :—

1916.

Thursday, November 23rd.—Sixty-ninth Ordinary General Meeting.

Presidential Address by Mr. F. E. Wentworth-Sheilds, M.Inst.C.E., etc.

Thursday, December 21st.—Seventieth Ordinary General Meeting.

Paper by Prof. Henry Adams, P.-P.C.I., M.Inst.C.E., etc., on " Pile Driving and the supporting power of Piles."

1917.

Thursday, January 25th.—Seventy-first Ordinary General Meeting.

Paper by Mr. C. R. Peers, Chief Inspector of Ancient Monuments, H.M. Office of Works, on " The care of ancient monuments."

Thursday, February 22nd.—Seventy-second Ordinary General Meeting.

Paper by Mr. Robert N. Sinclair, M.C.I., on " Southampton Docks : Re-modelling of an old Dry Dock."

Thursday, March 22nd.—Seventy-third Ordinary General Meeting.

Paper by Mr. W. Cleaver, M.Inst.C.E., on "The rational design of Reinforced Concrete wharves and jetties, with particular reference to those for Wet Docks having a permanent water level."

Thursday, April 26th.—Seventy-fourth Ordinary General Meeting.

Paper by Mr. H. C. Johnson, M.C.I., on "A method of proportioning material for Concrete."

The thanks of the Institute are due and are hereby tendered to the authors of papers.

The meetings during the past Session have been well attended.

As the result of a ballot among Members of Council, the bronze medal for the best paper read in 1915-16 Session was awarded to Dr. Oscar Faber, D.Sc., M.C.I., etc., for his paper entitled, "Shearing resistance of Reinforced Concrete Beams."

In the previous Annual Report it was stated that the Institute, in response to a request from the Advisory Council appointed by the Committee of the Privy Council on Scientific and Industrial Research (now established as the Department of Scientific and Industrial Research), had submitted a scheme of Research on Concrete and associated materials, and that a number of meetings of the Committees of the Institute had been held in connection therewith, and that deputations had waited upon the Officers of the Research Council to place details before them.

A scheme was eventually formulated for the undertaking of tests on the properties of various local sands and coarse materials and concretes made therefrom. A Joint Committee was appointed consisting of the Science Standing Committee of the Institute and representatives of the various technical institutions, who were willing to co-operate by undertaking tests in their laboratories and with their staffs. The Committee have been further strengthened by the addition of the following representatives of various Government Departments and Societies :—

War Office—Major-General Sir G. K. Scott-Moncrieff, K.C.B.

H.M. Office of Works—J. H. Markham, Esq., A.R.I.B.A.

Institute of Builders—G. M. Burt, Esq.

A programme was duly drawn up involving an eventual estimated expenditure of approximately £4,000, and an application was made for a grant of £830 for the first year's work. The Institute has undertaken to bear the cost of printing the results of the research, and the management of the scheme is in the hands of the Science Committee acting under the Council of the Institute. The Institute expressed its willingness to appeal to the technical public for contributions to the research fund, but thought it best to defer such appeal until after the war. The Research Council agreed with this, and has made a grant of the £830 required for the first year's work. A number of institutions are not able, owing to the war, to undertake tests at present, but it is expected that they will be able to co-operate later. Some delay in starting was caused by the difficulty of obtaining the necessary apparatus owing to the war, but the following laboratories have begun work and the progress at each centre is recorded as follows :—

Birmingham University (Prof. F. C. Lea, D.Sc.).—Test cubes made recently from various aggregates.

Bradford Technical College (Prof. G. F. Charnock, M.Inst.C.E.).—Local aggregate decided upon and casting of specimens now proceeding.

University College, Cork (Prof. C. W. L. Alexander, M.Sc.).—All specimens made and some of the tests already conducted.

University College, Dublin (Prof. P. F. Purcell, M.A.).—All specimens made and some of the tests conducted. In addition, tests being made for granulometric composition.

Edinburgh University (Prof. T. Hudson Beare, B.Sc.).—Test cubes made recently from various aggregates.

Municipal School of Technology, Manchester (Principal J. C. M. Garnett, M.A.).—Test cubes expected to be put in hand immediately.

Royal Technical Institute, Salford (Principal B. Prentice, B.Sc.).—Test cubes expected to be put in hand immediately.

Full details of the scheme will be published when the results of the research are reported to the Members, but briefly the scheme is as follows:—Concretes will be made from a variety of aggregates mixed in the familiar proportions of 1 : 1½ : 3 and 1 : 2 : 4. Others will be made equally rich in cement, but with the proportions of sand to stones varied. These concretes will be tested for strength, permeability and other properties. In this way it is hoped to discover not only the relative value of various aggregates, but also the most advantageous way of using them.

The following were appointed as delegates on a special Commission formed by the British Fire Prevention Committee to conduct an inquiry into the fire resistance of certain structural materials:—

Mr. D. B. Butler and
Mr. H. D. Searles-Wood.

The Special Committee which was appointed to consider and report on the relations between the architect and the reinforced concrete specialist and structural engineer made a report to the Council, which was forwarded to the Royal Institute of British Architects. It is hoped that that Institute will issue an expression of opinion on the subject.

The first examination of the Concrete Institute has been deferred until after the war.

Prof. Henry Adams, the Superintending Examiner of the Institute, has been appointed to represent the Institute at a Conference of Examining Bodies, held at the Board of Education, to deal with educational facilities for British Prisoners of War. The Conference has drafted the following statement:—

"Realising that many British Prisoners of War abroad have made great efforts to pursue systematic courses of study, and that arrangements are in existence for recording the work done by them and in some cases for examining them, the following bodies are prepared to recognise in a liberal spirit any work done, or examinations passed by such prisoners while in captivity, and also, in cases where such prisoners on their return home may apply for examination, to arrange, so far as practicable and consistent with educational effectiveness, to examine them without delay and in a manner suited to their circumstances." The Council has stated that the Concrete Institute is willing to act in the manner suggested.

The Conference which was convened by the District Surveyors' Association, and on which the Institute has representatives, to consider the interpretation of the L.C.C. (General Powers) Act, 1909, with reference to steel-frame buildings, has held a number of meetings in the past year and is engaged in drafting a report.

With a view to promoting the educational work of the Institute, and also to obtaining by sales to the public a contribution towards the cost of printing, it has been arranged that Messrs. B. T. Batsford, Ltd., of 94, High Holborn, shall act as publishers of the Institute's Transactions, Reports, Papers, etc. It is intended to issue papers in separate pamphlet form as well as in the Transactions.

The Committees appointed by the Council for the Session were as follows:—

THE FINANCE AND GENERAL PURPOSES COMMITTEE.

Chairman—Mr. E. Fiander Etchells.

Ordinary Members—Professor Henry Adams, Mr. J. E. Franck, Mr. Charles F. Marsh, Mr. H. D. Searles-Wood, Sir Henry Tanner, Mr. H. J. Tingle, Mr. E. P. Wells and Mr. G. C. Workman.

Ex-officio—The President, and the Chairman of each Standing Committee.

THE SCIENCE STANDING COMMITTEE.

Chairman—Mr. M. E. Yeatman.

Vice-Chairman—Mr. W. G. Perkins.

Hon. Secretary—Mr. Ewart S. Andrews.

Ordinary Members—Professor Henry Adams, Mr. H. K. G. Bamber, Professor T. Hudson Beare, Mr. D. B. Butler, Col. J. D. Cormack, Mr. E. Fiander Etchells, Dr. Oscar Faber, Mr. J. Ernest Franck, Mr. H. C. Johnson, Mr. Chas. F. Marsh, Dr. J. S. Owens, Mr. A. R. Sage, Mr. H. D. Searles-Wood, Mr. R. H. Harry Stanger, Mr. R. W. Vawdrey, Mr. E. P. Wells, and Mr. F. E. Wentworth-Sheilds.

THE REINFORCED CONCRETE PRACTICE STANDING COMMITTEE.

Chairman—Mr. S. Bylander.

Vice-Chairman—Mr. G. C. Workman.

Hon. Secretary—Mr. R. W. Vawdrey.

Ordinary Members—Professor Henry Adams, Mr. Ewart S. Andrews, Mr. Percy J. Black, Mr. J. F. Butler, Dr. O. Faber, Major J. Petrie, Mr. F. Purton, Mr. Lewis H. Rugg, Mr. A. Alban H. Scott, Mr. Archibald Scott, Mr. H. D. Searles-Wood, Mr. T. B. Shore, Mr. B. Taylor, Mr. J. M. Theobald, Mr. T. A. Watson, Mr. E. P. Wells, Mr. F. E. Wentworth-Sheilds, and Mr. M. E. Yeatman.

THE PARLIAMENTARY STANDING COMMITTEE.

Chairman—Mr. J. Ernest Franck.

Vice-Chairman—Mr. Osborn C. Hills.

Hon. Secretary—Mr. P. J. Black.

Ordinary Members—Professor Henry Adams, Mr. W. E. A. Brown, Mr. E. Fiander Etchells, Mr. Matt. Garbutt, Mr. W. G. Perkins, Mr. E. O. Sachs, Mr. L. Serraillier, Mr. E. P. Wells, Mr. F. E. Wentworth-Sheilds and Mr. G. C. Workman.

The Members of Council chosen to retire under the Rules of the Institute were as follows:—

Mr. Matt. Garbutt, F.R.I.B.A.,
Mr. A. Alban H. Scott, V.P.S.A.,

who were not eligible for re-election.

The Council nominated the following:—

Mr. Percy J. Black, District Surveyor for Wandsworth (East) and Battersea (Central), Member of Reinforced Concrete and Parliamentary Standing Committees.

Mr. W. E. A. Brown, A.R.I.B.A., Member of Parliamentary Standing Committee.

Mr. Edgar H. Homan, partner in Homan and Rodgers, Constructional Engineers.

Mr. Bertram L. Hurst, Assoc.M.Inst.C.E., A.M.I.Mech.E.

Mr. A. R. Sage, Assistant Principal of London County Council School of Building, Member of Science Standing Committee.

The election resulted as follows:—

Black, P. J. ...	...	...	96
Brown, W. E. A.	...	...	87
Sage, A. R. ...	...	...	84
Hurst, B. L. ...	...	...	77
Homan, E. H.	...	...	52

The first four were therefore elected.

The Council regrets to record the decease of:—

Killed in Action—

Capt. W. H. Morton-Johnson, M.A., F.R.G.S. (July 2nd, 1916).

Sec. Lieut. William Bell (July 26th, 1916).

Died of Wounds—

Sec. Lieut. H. Maguire, N.E.R., Bishop Auckland.

Died—

A. R. Debman, Mount Pleasant, Plymouth.

J. P. Harvey, 112, Kilmorie Road, Forest Hill.

S. Godden, Royal State Railways, Southern Line, Siam, Straits Settlements.

Several donations to the Library have been received by the Council from authors, publishers, and from kindred societies, and the Council expresses thanks to the donors. A list of books received will be published in the Transactions.

Finance and General Purposes Committee.

The Finance and General Purposes Committee have held regular meetings preliminary to each Council Meeting, and the general results of their deliberations are contained in the foregoing particulars of the Council's work for the year.

Science Standing Committee.

The work of this Committee during the past year has chiefly been concerned with the details of the research scheme above referred to. In addition, the Committee have considered the suggested amendment of the London Building Acts and Building Bye-Laws generally, and it is hoped that something will be done in the matter in conjunction with other societies. The Committee have also advised

the Engineering Standards Committee at the request of the latter respecting the use of special steels for reinforced concrete.

REINFORCED CONCRETE PRACTICE STANDING COMMITTEE.

The Committee have been engaged in drafting a Report, entitled:—"Recommendations to Inspectors, Clerks of Works and Foremen concerning the execution of Reinforced Concrete Work."

The Parliamentary Standing Committee have not held any meetings.

It is much regretted that, owing to pressure of war work, Mr. H. Kempton Dyson, who has been connected with the Institute since its foundation, has been obliged to resign his position as Secretary. He has been asked, and has consented, to act, *pro tem.*, as Honorary Secretary, so as to assist the new Secretary in his duties. Mr. Percy L. Marks, M.J.I., has been appointed to succeed him.

THE PRESIDENT moved the adoption of the Report and Balance Sheet.

Mr. H. D. SEARLES-WOOD, F.R.I.B.A., who seconded, expressed the hope that at the end of the war the Council would resume the printing of the discussions.

THE PRESIDENT said that was the intention.

Mr. E. LAWRENCE HALL suggested that it might be possible to issue the printed reports now and to make a charge for them to those members who wished to have copies.

THE PRESIDENT said the difficulty at the present time was that paper was so dear and all kinds of labour, including printing, were also so very expensive, that it would not pay to do this, for the reason that the number of copies purchased might not justify the expense involved. As it was, the Council was incurring considerable expense in printing the discussions to the extent mentioned in the report, and he thought the members would have to bear with the Council and postpone further printing until happier times. Next year probably they would get more printing done—he could not say how much at the moment—but he assured the members that the Council had got this matter very much at

heart and would not postpone the printing a moment longer than it could help.

The Scrutineers reported that the following had been elected as members of Council:—P. J. Black, W. E. A. Brown, A. R. Sage and B. L. Hurst.

On the motion of Mr. R. H. Owen, seconded by Mr. E. L. Hall, Messrs. Monkhouse, Stoneham and Co. were re-appointed auditors for the current year at a fee of three guineas.

THE PRESIDENT announced that the Institute's medal for the best paper read during the 1915-16 session had been awarded to Dr. Oscar Faber, D.Sc., for his paper entitled, "Shearing resistance of Reinforced Concrete beams." He was sure that those who heard the paper were very much impressed with the importance of it, both theoretically and practically. It put forward a theory which bade fair to revolutionise the design of reinforced concrete and there was no doubt that the medal was well deserved. He was exceedingly sorry that Dr. Faber was detained on some very urgent work for the Admiralty and was not able to be present to receive the medal, but he was sure they would all like the Secretary to send it to him with an expression of good will and hearty congratulation.

On the motion of Mr. Lucien Serraillier, seconded by Mr. H. D. Searles-Wood, a hearty vote of thanks was accorded to the President for his services during the past session.

INCOME AND EXPENDITURE ACCOUNT.

Dr. Year Ending December 31, 1916. *Cr.*

INCOME.

	£ s. d.	£ s. d.
To Annual Subscriptions		726 3 4
,, Special Subscriptions		15 15 0
,, Students' Subscriptions ...		6 18 6
,, Entrance Fees		16 16 0
,, Sundry Receipts—		
Various Receipts	3 5 2	
Advertisements	16 4 8	
		19 9 10
		£785 2 8
		£ s. d.
,, Balance brought down		0 10 4
		£0 10 4

EXPENDITURE.

	£ s. d.
By Office Salaries	315 10 0
,, Office Rent, Hire of Hall, Cleaning, Lighting, Heating	132 18 0
,, Printing, Reporting, etc.	231 14 1
,, Postages, Telegrams, etc.	27 15 6
,, General Expenses	29 6 7
,, Accountancy	8 8 0
,, Stationery	26 0 2
,, Amount written off Furniture for Depreciation	13 0 0
,, Balance carried down	0 10 4
	£785 2 8
	£ s. d.
,, Balance, being excess of Income over Expenditure, 12 months to date, as per Balance Sheet	0 10 4
	£0 10 4

BALANCE SHEET.

Dr. Year Ending December 31, 1916. *Cr.*

LIABILITIES.	£ s. d.
To Current Liabilities	252 13 9
,, Life Members' Subscriptions	42 0 0
	£294 13 9

ASSETS.	£ s. d.	£ s. d.
By FURNITURE—		
As at December 31, 1915 ...	127 0 0	
Less Depreciation	13 0 0	
		114 0 0
,, CASH—		
At Banker's, Current Account	111 2 6	
Petty Cash	16 17 2	
		127 19 8
,, Balance, being excess of Expenditure over Income as at December 31, 1915 ...	53 4 5	
Deduct Balance, being excess of Income over Expenditure, 12 months to date, as per account ...	0 10 4	
		52 14 1
		£294 13 9

We report to the Members that we have obtained all the information and explanations we have required, and that we have examined the above Balance Sheet dated 31st December, 1916, with the Books and Vouchers of the Concrete Institute. We certify that such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institute's affairs according to the best of our information and the explanations given us, and as shown by such Books and Accounts.

(*Signed*) MONKHOUSE, STONEHAM & CO.,
Chartered Accountants,
SALISBURY HOUSE,
LONDON, E.C.
5th June, 1917.

FOR THE CONCRETE INSTITUTE—
(*Signed*) F. E. WENTWORTH-SHEILDS, *President*
E. FIANDER ETCHELLS, *Chairman of Finance Committee.*
H. KEMPTON DYSON, *Secretary.*

SEVENTY-FIFTH ORDINARY GENERAL MEETING.

THURSDAY, NOVEMBER 22ND, 1917.

The PRESIDENT then opened the SEVENTY-FIFTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE by calling upon Lieutenant J. Newton Friend, D.Sc., to read his paper entitled, "The Corrosion of Iron and Steel with special reference to Reinforced Concrete."

THE CONCRETE INSTITUTE :

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, Etc.

Date of Reading : November 22nd, 1917.

The Corrosion of Iron and Steel, with Special Reference to Reinforced Concrete.

By J. NEWTON FRIEND, D.Sc., Ph.D., F.I.C.,

Carnegie Gold Medallist.

Owing to the unprecedented importance of iron in its relation to modern civilisation the early history of the metal possesses peculiar fascination for the antiquary. It is safe to assert that the wonderful progress which has marked our path during the last 100 years would not have been possible had not the earth possessed an abundant supply of iron ore. In whichever direction we cast our eyes, articles of iron, large and small, essential and ornamental, meet our gaze. It is iron in some form or other that constitutes the backbone both of our railways and of our mercantile marine. Without these rapid means of transport the huge populations of London and our larger cities could not be fed and supplied with the necessaries of civilised life as we know it to-day. Again, reinforced concrete, in which we are all specially interested, owes what strength and adaptability it possesses almost entirely to its iron frame. I am sufficiently optimistic to believe that a brilliant future is already assured for this material.

In the sequel the term iron is used to denote the various kinds of iron and steel without differentiation.

EARLY HISTORY OF IRON.

There can be little doubt that man, in the days of the early childhood of the human race, would seize upon any

stones, branches of trees, or other hard materials lying at hand for purposes of offence or defence. As years rolled by he would learn to prepare in moments of quiet for future emergencies and would thus single out stones, etc., which appeared to him specially suitable for the purpose, and keep them by him. Later on it would occur to him to improve upon the natural shapes by chipping and he would soon discover that flint is particularly amenable to such treatment. Thus would originate the flint weapons and tools which have been discovered in large quantities in modern times and which antiquaries have made use of to throw interesting light upon the manner in which primitive man lived during what has been aptly termed the "stone age."

In all probability during his search for suitable stones early man occasionally stumbled across meteoric iron. Finding that it did not crack on being hammered,* that it possessed great tenacity and admitted of being rubbed to a fine, hard edge, he would greatly prize it and pieces would be handed down from father to son as valued heirlooms, far too precious and rare to be buried in the warrior's grave. This does not constitute the beginning of what antiquaries term the "iron age," for man, at the period of which we speak, had no idea of the connection between meteoric or native iron and the red or brown earthy hæmatites around him. He regarded the iron as a particularly useful and rare kind of stone, and probably there the matter ended in so far as he was concerned.

That such might well be the case has been repeatedly illustrated by the observations of travellers within historic times. Sabine, who accompanied Ross in his Arctic explorations in 1818, relates that certain Eskimos, who visited the party, carried knives consisting of blades, of what was afterwards proved to be meteoric iron, set into bone handles. The pieces of iron had been detached with great labour from the softest of three masses of metal of meteoric origin at Melville Bay, and had then been beaten flat between stones in the cold condition.

This undoubtedly represents exactly what primitive man would do in Europe ages ago. It has been suggested that the amount of meteoric iron on the surface of the earth is so small that early man would probably seldom have an

* Zimmer, *J. Iron Steel Inst.*, 1916, II., 306.

opportunity of seeing any and only in rare cases would he ever have used it. An answer may be found in the fact that there is more meteoric iron known to science than many people believe. Zimmer estimates its amount at approximately 246 tons, and in the days of prehistoric man there were all the accumulations derived from meteoric showers of the previous ages to draw upon. Hence, it is reasonable to suppose that meteoric iron must have been rather more plentiful than now, particularly when it is remembered that, owing to its nickel content, celestial iron is frequently highly resistant to corrosion.

Many centuries elapsed, perhaps indeed ages, before man discovered that certain "stones" on being heated in the fire yielded a new "stone" capable of being hammered into useful shapes, and differing from the original stone in most of its other properties. This new product we now call copper or bronze, according to its composition. At first, no doubt, it was a matter of accident whether bronze or copper was produced.* In districts where the two ores occur in association, they would be reduced together as one and the same. Ultimately, however, it would be observed that the bronze was not a simple substance, but a mixture, and in this manner metallurgical knowledge gradually progressed both during and after the transition of man from the stone age to the "bronze age."

Very considerable metallurgical skill was ultimately attained and eventually iron ores were reduced to the metal and an iron industry was established. This simple beginning heralded the dawn of the "iron age." The question now arises as to how many years iron—whether native, meteoric, or manufactured—has been known to and used by different peoples. Just as the nations to-day differ in the relative degrees of their civilisations, so in past ages some of the peoples were living in their stone age whilst others were using implements of bronze, and yet others had become familiar with iron. Thus, Britain was passing through her stone period at a time when iron was already known in Assyria, in Egypt, and probably also in China.† According to Petrie‡ iron was known in Egypt some 7000 to 6000 B.C., although it was never in general use until about 500 B.C.

* Compare Gowland, *Huxley Memorial Lecture*, 1912.
† See Brough, *J. Iron Steel Inst.*, 1906, **I**, 233.
‡ Petrie, *ibid*, 1912, **I**, 182.

England's most important centres of the iron industry. The introduction of cast iron made it possible to utilise our ores to far greater advantage than would otherwise have been the case and constitutes an important milestone on the upward path of civilisation. At the present time some 80 million tons of pig iron are made annually, and the different varieties of iron and steel manufactured are so numerous that only the expert can appreciate them.

HISTORY OF CORROSION.

The tendency for iron to rust upon exposure to air is too pronounced to have escaped the notice of even the most primitive workers of this metal. Pliny, who compiled his famous *Natural History* nearly 2,000 years ago, waxes eloquent on the subject. "Nature," he writes,* "in conformity with her usual benevolence, has limited the power of iron by inflicting upon it the punishment of rust; and has thus displayed her usual foresight in rendering nothing in existence more perishable than the substance which brings the greatest dangers upon perishable mortality."

Pliny also knew that some kinds of iron are less resistant to corrosion than others, and distinctly mentions† a species that "is more particularly liable to rust." He further states‡ "that there is in existence at the city of Zeugma, upon the Euphrates, an iron chain by means of which Alexander the Great constructed a bridge across the river, the links of which that have been replaced having been attacked with rust, while the original links are totally exempt from it."

This passage is not only remarkable as being a very early, if not indeed the earliest, statement of the relative corrodibilities of two kinds of iron; it is also of peculiar psychological interest in that it emphasises the unity of human nature throughout the ages. Pliny argues that even in his day the older metal was better than the new. We are involuntarily reminded of the man who complained that "Punch's" jokes are not now as good as they used to be; to which "Punch" pithily replied, "They never were."

Although rusting of iron has been observed for thousands of years, it is only comparatively recently that com-

* Book 34, Chap. 40. Translated by Bostock and Riley, 1857.
† *Ibid*, Chap. 41.
‡ *Ibid.*, Chap. 43.

mercial interests have demanded a thorough scientific study of the subject; and as iron becomes more and more the consort of civilisation, so will the need of combating corrosion become proportionately greater.

CONDITIONS ESSENTIAL TO THE CORROSION OF IRON.

Before passing on to consider the means of preventing the corrosion of iron it may be well for us to pass briefly in review a few of the more important facts concerning the cause of rust formation.

1. *Water, alone, is without appreciable action upon iron at ordinary temperatures.* This is well illustrated by the tubes exhibited here containing iron and air-free water. The tubes were hermetically sealed 11½ years ago. Apart from the merest trace of tarnishing, which can only be detected under a powerful light, the metals appear to have undergone no change whatever.

2. *Water vapour is without visible action upon iron at ordinary temperatures.* Indeed iron may be heated for prolonged periods in steam up to about 300° C. without undergoing any apparent change. At 350° C. and somewhat above, ferrous oxide is produced, the surface of the metal being tarnished and gaseous hydrogen evolved.* At still higher temperatures magnetic oxide of iron results and forms a skin on the surface of the metal, which tends to protect the under layers from attack. This, however, is not rusting in the ordinary acceptation of the term. It is oxidation, and is the principle of the Barff process of protecting iron from corrosion.

3. *Dry air or oxygen has no visible action upon iron at ordinary temperatures,* but when the temperature is raised to 220° C. iron acquires a pale yellow tint and at higher temperatures becomes straw coloured, purple, and finally blue. These are known as tempering colours and are caused by thin superficial layers of oxide, as is proved by the fact that they are not produced even by prolonged heating in vacuo.† They are obtained even in perfectly

* Friend, *J. West Scotland Iron Steel Inst.*, 1910, **17**, 66.
J. Iron Steel Inst., 1909, II., 172.
† Roberts, *Trans. Inst. Mech. Eng.*, 1881, p. 710.

dry air, such as that resulting from prolonged exposure to phosphorus pentoxide.* These layers tend to protect the underlying metal from attack and differ from rust in being anhydrous and tenacious. Rust, on the other hand, is usually hydrated, porous, hygroscopic, and friable.

4. *A mixture of water vapour and air is without action on iron at ordinary temperatures,* provided no liquid water is allowed to condense on the metallic surface. This was clearly demonstrated in 1905 by Dunstan and his co-workers,† who kept iron in tubes at constant temperature exposed for three months to moisture and air without any sign of rust forming.

On allowing the temperature to fluctuate, however, in order that liquid water might form upon the iron, corrosion readily took place. This disposes of the possibility that rusting is a simple case of direct oxidation such as occurs when the metal is heated in air.

From the foregoing it is clear that oxygen and liquid water are essential to corrosion.‡

THE CHEMICAL NATURE OF RUST.

Rust is essentially hydrated ferric oxide, the extent of hydration varying considerably according to circumstances. In colour rust ranges from brown to red, and it usually happens that the red is less hydrated than the brown. Some ferrous oxide is generally present, particularly if the metal has not been completely oxidised away. This oxide has a blackish appearance and may be found in the innermost layers close to the metal.§ Rust also contains free water in addition to that chemically combined with it, for it is a hygroscopic, porous mass. It also readily absorbs carbon di-oxide from the air. These two properties serve to render it an active stimulator of corrosion. The carbon di-oxide dissolves in the water to carbonic acid, which attacks a portion of the iron yielding ferrous carbonate. This, in turn, is oxidised by the air to rust.

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* Friend, *J. Iron Steel Inst.*, 1909, II., 172.

† Dunstan, Jowett and Goulding, *Trans. Chem. Soc.*, 1905, **87**, 1548.

‡ We are not here concerned with the academic question as to whether or not perfectly pure iron will corrode in perfectly pure water and oxygen. Perfectly pure materials do not appear in commerce.

§ See Analyses by Moody, *Trans. Chem. Soc.*, 1906, **89**, 726.

According to Bauermann,* when iron rusts it expands to some ten times its original volume. This may possibly be somewhat of an exaggeration, but the fact remains that very appreciable expansion does take place on rusting, a property that is made use of by the plumber in his rust joints. This expansion is, to the worker in ferro-concrete, a serious problem. If the metal once begins to rust a cracking of the concrete is inevitable; more air and water enter so that corrosion now proceeds apace, and the structure becomes proportionately weakened.

THE INFLUENCE OF INORGANIC SALTS UPON THE CORROSION OF IRON.

The influence of aqueous solutions of inorganic salts upon the corrosion of iron depends upon a variety of factors such as, for example, the chemical nature of the salt, its concentration and the temperature of the solution.

At ordinary temperatures a very dilute solution of sodium carbonate is considerably more corrosive than tap water. But if the concentration be increased to 0.25 per cent. and above, the metal is entirely protected from rusting. Again, a 3 per cent. solution of common salt at about 10° C. is much more corrosive than tap water at the same temperature, but as the temperature rises the relative corrosivity falls, so much so that at 21° C. the solution is appreciably less corrosive than tap water. Since sea water contains some 3 per cent. of sodium chloride it is of interest to inquire into the effect upon its corrosive powers of diluting it with river water, for this occurs in nature at the mouths of many rivers and has to be reckoned with by the engineer.

This is well illustrated by Fig. 1 (page 10).

The broken line represents the loss in weight, due to corrosion, of iron in tap water. This, for the sake of simplicity, is taken as 100 for each temperature studied. It will be observed that at 18° C. (64° F.) and above, all dilutions of sea water are less corrosive than tap water, whilst at lower temperatures they are more corrosive.

Figure 2, showing the relative corrosive action of sea water at various temperatures, is very interesting. At 11° C. sea water is considerably more corrosive than tap water.

* Bauermann, *J. Iron Steel Inst.*, 1888, II., 135.

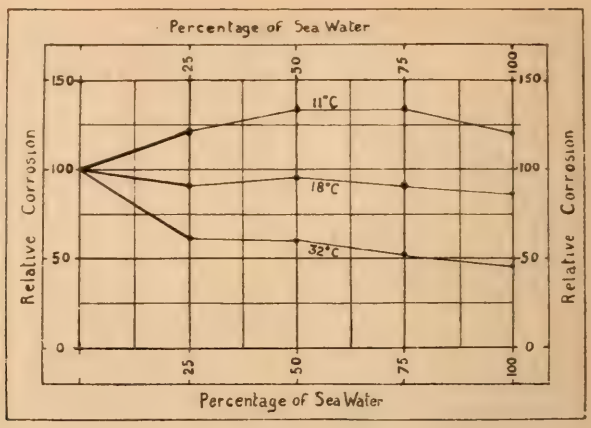

FIG. 1.

At 13° C. the two waters act similarly, whilst at all higher temperatures sea water is less corrosive than tap water.*

The practical importance of these results is patent. In the western part of the tropical Pacific Ocean a temperature of 32° C. (90° F.) is frequently attained, whilst in

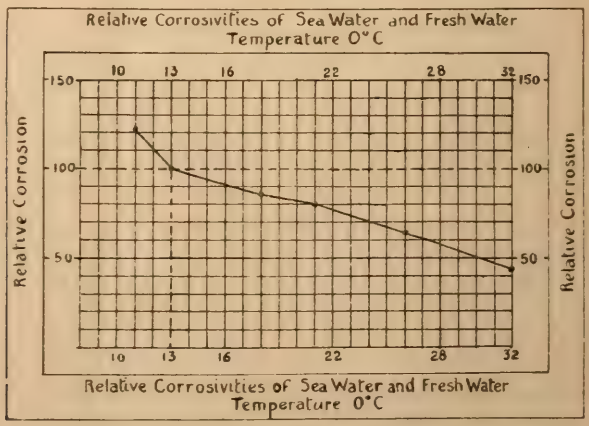
Relative Corrosivities of Sea Water and Fresh Water
Temperature 0°C
Relative Corrosion
Relative Corrosivities of Sea Water and Fresh Water
Temperature 0°C

FIG. 2.

* Friend and Brown. *Trans. Chem. Soc.*, 1911, **99**, 1302.

the Red Sea and Persian Gulf temperatures of 34.4° C. (94° F.) and 35.5° C. (96° F.) respectively have been registered. Such waters, therefore, are much less corrosive than river waters at the same temperatures.

In the Arctic Ocean, on the other hand, the temperature often lies considerably below 0° C. (32° F.) and such waters are relatively much more corrosive than fresh or river waters.

Between these two extremes all grades of temperature occur and according as they lie above or below 13° C. (58.4° F.) so is their relative corrosive action less or greater than that of river water.

An increased measure of interest attaches to these results in view of experiments in progress, mainly in Scandinavia, with intent to use ferro-concrete in the construction of ships.* The shipping shortage, largely consequent upon submarine losses, is felt particularly keenly in Scandinavian countries where serious difficulties have arisen as a result of the scarcity of metals. Although ferro-concrete barges have already been constructed for quiet waters, the problem of building sea-going vessels to be propelled by their own engines is by no means so simple. Lloyd's Register has approved plans up to 500 tons and the maximum weight of any projected vessel is of the order of 1,000 tons. Now concrete is weak under tension and reinforcement is designed to take the tension and leave the concrete to deal with compression. This is just where the difficulty comes in as regards the construction of ships. There is great danger of cracks developing leading to serious corrosion, so that the behaviour of these ferro-concrete ships will naturally be watched with the greatest of interest by engineers. Their life will no doubt greatly depend upon the imperviousness of the concrete to sea water, upon freedom from cracks and upon the resistance offered by the reinforcing metal to the corrosive action of sea water.

THE INFLUENCE OF ALKALIES UPON THE CORROSION OF IRON.

For many years it has been known that alkalies, if present in sufficient concentration, will completely inhibit corrosion. The merest traces of caustic soda or potash will

* See account in *Nature*, November 15, 1917, p. 205.

suffice to prevent rusting in aqueous solution provided such solution is protected from neutralisation by the carbon dioxide of the air. Should, however, large supplies of air gain access, carbonates are produced and these greatly accelerate corrosion unless the concentration of alkali is sufficiently great to yield 0.25 per cent. solution of carbonate, as has already been mentioned. Lime, of course, behaves similarly to caustic soda or potash. Hence, in attempting to protect iron permanently with free alkalis, such as lime, it is necessary to consider, not merely the protection afforded by fresh caustic lime, but that which will be afforded when the atmosphere has converted the lime into carbonate.

An interesting case arises when iron is immersed in alkaline solutions containing inorganic salts. For example, iron will remain bright in a one per cent. solution of caustic potash for an indefinite time, but upon addition of potassium chloride corrosion readily takes place. It is possible, however, to increase the alkali to such an extent that corrosion is entirely prevented, no matter how concentrated the solution of chloride. The minimum amount of alkali required rises with the percentage of chloride until saturation of the latter is arrived at. This is indicated in Figure 3. AB represents the solubility curve of potassium chloride in aqueous solutions of caustic potash, whilst CD shows the minimum amounts of caustic potash required to neutralise

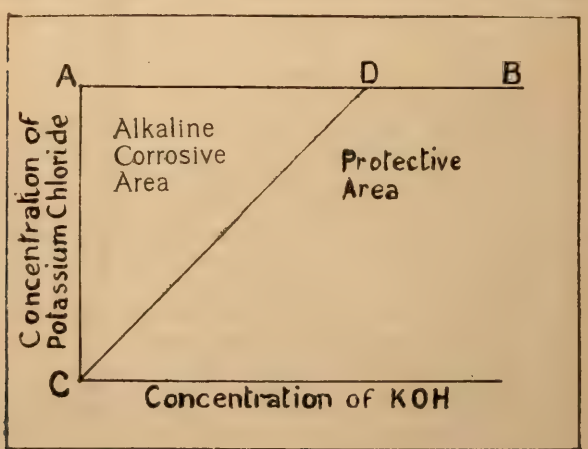

FIG. 3.

the action of corresponding quantities of chloride. Within the area ACD, therefore, corrosion can take place; but outside this area corrosion is impossible.*

A curious point about this type of corrosion in alkaline solution is the fact that it invariably takes the form of pitting.† Lumps of rust grow at various points on the surface of the metal, and, when scraped away, leave holes or pits in the same. The rust invariably contains a dark oxide close to the metal, and surrounded by ordinary brown hydrated ferric oxide. Most probably the pitting originates at points where traces of impurity are present. These traces are exceedingly difficult to remove, and are readily found on etching the surfaces of even the purest commercial irons. For example, Kahlbaum's pure electrolytic foil readily pits under these conditions, whereas in ordinary tap water or in aqueous solutions of neutral salts it usually rusts evenly over its entire surface.

These observations demand the serious attention of boiler engineers, inasmuch as weakly alkaline feed waters are liable to produce serious trouble.‡ It is not difficult to imagine that a large iron boiler might very well lose several pounds in weight through a uniform superficial corrosion and not be seriously affected thereby. Yet if a hole were caused by pitting the effect might be disastrous, even although the total loss in weight were only half an ounce.

The remedy in these cases appears to lie in increasing the alkalinity and thus to bring the waters within the sphere defined as the protective area in Figure 3.

If now we replace the potash by lime and the chloride by silicates and sea water we have the condition of things represented by iron in concrete and exposed to the sea, as, for example, in dock piles.

Our subject has thus an important bearing upon the work of the concrete engineer, which we shall now proceed briefly to discuss.

THE PRESERVATION OF IRON IN CONCRETE.

From the foregoing it is evident that the preservation

* Friend, *J. Iron Steel Inst.*, 1911 (Carnegie Scholarship Memoir).
† Friend, *Science Progress*, 1913, **5**, 202.
‡ See Lyon, *Iron Age*, 1914, **93** 1005. *J. Amer. Soc. Naval Eng.*, 1912, **24**, 845.

of iron in concrete may be effected in one or more of three ways, namely :—

1. By complete exclusion of air.
2. By complete exclusion of water.
3. By rendering the concrete sufficiently alkaline to place it within the protective area (Fig. 3).

If the engineer can make his concrete conform perfectly to any one of these conditions he has achieved his object, for the reinforcing metal will not rust. Unfortunately, in practice, materials cannot be relied upon to yield perfect results and the engineer's best policy is to conform as nearly as is reasonably possible with all three conditions. In this way he may hope so to reduce the tendency to corrode as to render it negligibly small within finite time.

The following considerations therefore suggest themselves as worthy of careful study :—

1. None of the concrete materials should be too coarse, otherwise thorough mixing and good contact between the different ingredients will not be as perfect as is desirable.
2. It is essential to press or pun the mixture well into position in order to eliminate voids in so far as is possible. It is obvious that voids tend to increase permeability to water and air and are in consequence highly dangerous.
3. A sufficient thickness of concrete should be applied to the metal. If too thin the concrete may not be sufficiently impervious or it may crack mechanically and thus admit air and water to the metal.
4. Stray electric currents must be avoided. If the metal should become anodic, the tendency to rust would be greatly enhanced in consequence of the liberation of oxygen, and this, leading to cracking, would rapidly destroy the cement.*
5. Substances likely to contain acids or acid producing bodies should be avoided. Coke breeze and slags are cases in point, as they frequently contain injurious sulphur compounds.

* See Nicholas, *J. Iron Steel Inst.*, 1909, I., 659.

6. The concrete may be advantageously coated with some waterproofing material to render it still more impervious, provided such proofing is entirely free from acid or acid-producing substances.

It will be observed that certain of the above suggestions harmonise very well with those arrived at on entirely different grounds and published in the Report of the Science Standing Committee and read at the General Meeting of the Institute on March 9th, 1911.

FINIS.

Your patience has now been sufficiently taxed. Had time permitted it was my hope to deal with other important questions, such as the best metals to use in reinforcing concrete, the treatment of the metallic surface prior to encasing with concrete, and so on. These problems, however, must be relegated to some future occasion.

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DISCUSSION.

The President said the Paper was unique in the annals of the Institute. It was rather a new treatment of the subject so far as the Institute was concerned and would not fail to be of enormous practical utility.

Mr. H. D. Searles-Wood, F.R.I.B.A., V.-P.C.I., who proposed a hearty vote of thanks to the author, said the subject was one which he had tried to follow in various books, but he had never had it so clearly put before him as Dr. Friend had done in the Paper.

Mr. W. A. Green, M.A., M.C.I., in seconding the vote of thanks, said the Paper had been most fascinating and he wished it had been longer.

Mr. E. Fiander Etchells, F.Phys.Soc., V.-P.C.I., said that apparently the author adhered more closely to the electrical theory than to the electrolytic theory and he would not attempt to decide between the two. There seemed to be some truth in both. Three or four instances of rust had specially come before his notice. One was the case of a railway bridge, in which the web plates had rusted through from one main angle to the other and from one web stiffening to the other, and yet the bridge continued to carry the load. Presumably it was able to do so because the stresses in the first instance had been rather low and the main angles had been sufficient to take up any bending moment which came on after the web had corroded away. This shewed the desirability of allowing some margin of strength in the original design, rather than following very close methods of design. Another case was that of some lattice bars, 3in. by ½in., which he could easily break in his hands, so that the bars seemed to have been converted into rust right through. Another instance was that of a railway girder, the flange of which had extensive layers of rust ⅜in. thick. The result was that within a short period of time that bridge would have been lying at the bottom of a river. Again, it shewed the desirability of making provision for rust in the original design. He suggested that the provision should not be done on the question of stresses alone. Take the design of a steel chimney, for example; it could either be

designed to stand 50lbs. or 40lbs. wind pressure after the expiry of 10 or 15 years. It might then be designed for a stress of 6 tons per square inch, which would allow a little for corrosion, or it could be designed for 60lbs. wind pressure, bearing in mind that it would resist 30lbs. at the end of a number of years. That had a disadvantage, because if they wanted a safety factor of 2 to 1, the foundations must be designed to resist 120lbs. to the square inch wind pressure, which was not reasonable. Therefore, it would be better to design the chimney for the principal wind pressure at a certain stress, and having decided what the thickness of the steel should be, add an eighth or a quarter for corrosion. If the design was done on these lines there would not be the disadvantage of having to increase the foundations unnecessarily. Another instance of rust was that of some bars, which were exposed to the air and always gave trouble through rusting. It was therefore decided to have them cleaned and painted. When the scraping was done they were washed with a strong solution of soda. Then something happened to prevent the painting, but the soda solution seemed temporarily efficacious as a preservative. Yet another instance was that of a web, which was designed for 4 tons per square inch to take compressive stresses, but the web had rusted through until it was like so much paper.

Mr. C. H. W. Biggs said he had held for a good many years, and still held, that pitting was due to electrical action. This matter had been discussed in the electrical world over and over again, and the conclusion arrived at was the one he had mentioned, because there were all the constituents of an electric battery. The author had very aptly said that pure water would not corrode. He looked upon water as having a catalytic action and he had hoped they would have heard something of the action of moisture assisting a catalytic action. The point was, how were they going to stop this. He had heard of a great many things with which iron should be painted, but none of them seemed perfectly efficacious; but one of the latest that had been brought before his notice, viz., Futulin, he was told had advantages which ordinary paint did not have. It could be put on like paint, but it was elastic, and therefore a change of temperature did not set up any action. It was essential to stop this action, which was going on year by year. With 80 million tons of ore being turned into iron during the course of the year a loss by corrosion of 5 per cent. was extremely serious and if a preservative could be

used it was to the interest of the nation to use it. If anyone knew of a means which had been efficacious he hoped he would speak about it. He was continually being asked if there was a preservative which would prevent the corrosion of iron and steel work.

Mr. E. Lawrence Hall, M.C.I., referring to conclusion No. 6 in the Paper, said there were on the market a great many waterproofing compounds that might be mixed with concrete, and he was wondering whether any of them might contain matter which later would develop a tendency to destroy the iron, although keeping the water out of the concrete.

Mr. Ewart S. Andrews, B.Sc., M.C.I., said he would like to join issue with Mr. Etchells and say that if they were going to fail to design their steel work economically just because of some unknown contingency such as rusting—something which they could not measure—they would be putting their heads in the sand. They must obtain the information they required, and to do that there must be collaboration between the chemist and the metallurgist in order that the structural engineer should obtain the exact information necessary to design correctly. The chemist and the metallurgist must be encouraged to tell the structural engineer all they could, in order to get at the bottom of the question of corrosion. They should not allow for rusting in some indefinite haphazard sort of way, they should not attempt to alter design, but must endeavour to prevent rust. He doubted whether Mr. Etchells' examples *did* shew the wisdom of making allowance for rust which he seemed to suggest. He had come across a remarkable instance in America of a structure which holds up and for which there was no excuse. It was an ordinary road bridge of the flat truss type, and the bottom flange on one side had a hole right through it. That bridge was standing up because the top flange was held down so well by the bolts at the end, that it was acting as an arch. The fracture must have been several years old, because it had been found that the break had at some time or other been painted over.

Mr. Etchells said he had found a preparation known as Dr. Toch's paint more successful than the average painting. With regard to Mr. Andrews' remarks, either he had not made himself clear or Mr. Andrews had misunderstood him. There was really no conflict of opinion between them. He had suggested that provision should be made

for corrosion separately from the stresses. He was as anxious as Mr. Andrews that design should be as economical as possible and really they were in absolute agreement. They might say they wanted a structure to carry the load for 10 years; then they should make the calculations for the stress and add for corrosion what their experience told was right, say one-tenth inch in 10 years. If it were wanted to last 20 years then one-fifth inch would have to be added for rust, so that there was one thickness for carrying the load and another for standing the gradual decay of unprotected steel work. It would be better, as paint was cheaper than steel, to get the best paint and keep the steel painted, but that was partly a matter for the economist.

Mr. W. J. H. Leverton, M.C.I., asked Mr. Etchells whether, in the cases he had mentioned, painting had been neglected or had they been painted with inferior paint. He would also like to ask the author if he could give examples of steel which had decayed in reinforced concrete. A few years ago he was at Shoreham and noticed some reinforced groynes which had been broken down and some of the rods were very much rusted away. It was possible that the centering had been taken away too soon and the sea water allowed to attack the concrete before it was thoroughly set.

Mr. Etchells said, that in the cases he had mentioned, painting had been neglected. The work in each instance had been designed by an engineer and left to a manager to mismanage. He had economised on paint and lost his structure in every case. In connection with lead, it appeared that after the first layer was formed, the corrosion went no further. It seemed to protect the lead underneath, but with steel or iron it was quite different. After it was painted the sun made a blister and something happened to break the blister and oxygen attacked the steel underneath. Another layer of rust was formed and it seemed to give up its oxygen to a layer underneath, and so on right through to the heart of the steel. The steel then either rusted away in flakes, or in one or two rare instances it seemed to be converted into solid rust. In those cases where it had been converted into solid rust it was between high and low water level at the sea side, and the result was more like ironstone, a cross between stone and iron, and he was quite certain that the tensile strength of this solid rust was higher than theoretical people would be prepared to allow.

The PRESIDENT said it would be interesting to know whether there was a probability of rustless steel coming into general use. He had some knives which had never been cleaned on a board for two years; they had merely been washed in the ordinary way and there were no signs of corrosion. He believed they were made of steel with chromium in it and he had often wished he could have that steel for his reinforced concrete. The practical conclusions in the Paper were very interesting and he would like specially to refer to No. 6. That was a most important thing for the engineer who had to use reinforced concrete in sea water, which involved the most trying conditions in which reinforced concrete could be used. He had noticed a curious thing at Southampton, viz., that whereas the oldest marine structures had not suffered at all, some that had been built since had suffered in a most remarkable way, the sea water apparently getting through the concrete to the steel and rusting it, and eventually bursting open the concrete. At first he thought it might be due to electric currents, but this seemed doubtful. He had made some experiments in which steel tubes buried in concrete cylinders were connected to a dynamo through a resistance. The cylinders were partly immersed in a tank of sea water which was connected to the other terminal, making the steel the cathode. When the circuit was completed the sea water seemed to pass right through the substance of the concrete and boil up around the tube. Very soon the tube rusted and the concrete burst off. He also experimented with other similar cylinders, the outside of the concrete being coated with paint or tar. In such cases the paint or the tar formed a perfect protection, whereas those samples which were not painted cracked. That was interesting in shewing that a coating such as the author recommended would be useful as a protection not only against the ordinary atmospheric corrosion, but also against corrosion aggravated by electrolytic action.

Dr. FRIEND, replying to the discussion, said it was a general view that pitting was caused by the electric current generated by the difference in potential between the impurities and the iron itself. When he was a student at college every action which could not be explained was called catalytic. In the same way scientists endeavour to explain corrosion as electrolytic, but it was no real explanation to say that a difference of potential existed between the metal and the impurities. The question was, what caused that

difference of potential to exist? If that could be discovered, undoubtedly many difficulties would be solved. Mr. Leverton had asked as to the decay of steel in concrete. That was a large subject. All the cases which had come under his personal observation could be ascribed to failure to comply with one or other of the suggestions at the end of the Paper. No doubt it was not always possible to make perfect reinforced concrete, because of the limitations of materials; at the same time, if it were possible to follow perfectly any one of the suggestions he had made, he doubted very much whether steel would ever corrode in concrete. He could not discuss at the moment the best compositions of steel. Iron containing a low quantity of carbon would corrode much less than iron containing a higher amount. It was necessary to know the exact conditions under which the concrete was to be used, in order to say definitely the quality of metal that should be employed. Possibly on some future occasion he would be able to discuss some of these things. The knives the President had referred to contained $12\frac{1}{2}$ per cent. chromium. Some rustless knives which a friend of his had *did* rust after they had been used in pickles; and on analysing the pickles it was found that they contained sulphuric acid along with the acetic acid or vinegar. Therefore if rustless steel knives rusted they would know that probably a mineral acid was present.

SEVENTY-SIXTH ORDINARY GENERAL MEETING,

THURSDAY, DECEMBER 20TH, 1917.

THE SEVENTY-SIXTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held at Denison House, 296, Vauxhall Bridge Road, Westminster, London, S.W., on Thursday, December 20th, 1917, at 5.30 p.m.

THE PRESIDENT (Mr. F. E. WENTWORTH-SHEILDS, M.Inst.C.E.) was in the Chair.

The following gentleman was elected as

ASSOCIATE MEMBER.

DOUGLAS BRUCE BAIN, Engineering Department, Victoria Docks, Port of London Authority.

The following list of students, elected since May, 1916, was announced:—

November, 1916.—ALBERT M. TAYLOR, The British R.C. Engineering Co., Ltd., 1, Dickinson Street, Manchester.

March, 1917.—E. G. WILSON, Crystal Palace School of Practical Engineering.

June, 1917.—E. L. BREWIS, 3, Central Buildings, Westminster, S.W.

October, 1917.—AYE MAUNG, 60, Queen Victoria Street, E.C.4.

December, 1917.—F. G. THOMAS, The Trussed Concrete Steel Co., Ltd.

THE PRESIDENT then called in turn upon Mr. ELLIS MARSLAND and Mr. H. KEMPTON DYSON to read their notes upon "The Effects of Fire on Reinforced Concrete buildings as demonstrated by some recent examples." These notes were made further interesting by the projection of lantern slides, but the papers were not allowed to be made public under the regulations of the Defence of the Realm Act.

SEVENTY-SEVENTH ORDINARY GENERAL MEETING,

THURSDAY, JANUARY 24TH, 1918.

THE SEVENTY-SEVENTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held at Denison House, 296, Vauxhall Bridge Road, Westminster, London, S.W., on Thursday, January 24th, 1918, at 5.30 p.m., Mr. F. E. WENTWORTH-SHEILDS, President, in the Chair.

The following gentlemen were elected:—

ASSOCIATE MEMBER.

THOMAS FRANCIS DOWLING, 22, Mackenzie Street, Slough.

ASSOCIATE.

ERNEST JOSEPH NASON, Greenmill Square, Cape Town.

THE PRESIDENT then called on Mr. E. A. W. PHILLIPS, M.Inst.C.E., M.C.I., to read his Paper on "British Trade and the Metric System."

THE CONCRETE INSTITUTE:

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, Etc.

Date of Reading: January 24, 1918.

British Trade and the Metric System.

The above title has been assumed for this paper because it is the title of a book* on the same subject and because it is very appropriate, since the author's object is the increased commercial prosperity of the Empire. Before any more is said the author desires to define his position.

1. It is argued, that the book introduces a new metre and a new system, with disadvantages which hardly need mentioning; that the new metre is a "freak" metre; that it would not appeal to our present metric customers; that the simplification of the British system is merely collateral to the advantage the metric system would give us in the other markets of the world; and that the public generally could never be induced to adopt a new decimal standard. The author quotes all this with a view to shewing that he is acquainted with metric arguments. He has indeed been so since long before 1908, the year of the discovery of the Tripod, so that the first thing he wishes to impress upon his audience is the fact that he did not open his offensive without a full knowledge of the entrenchments he means to take.

2. Although what he has to say is of supreme importance to British trade throughout the Empire, it ought not to be assumed that he is acquainted with every trade custom and exigency. He offers trade a sure tool, which he is aware, from the investigations he has been able to make,

* "British Trade and the Metric System," by E. A. W. Phillips, M.I.C.E., M.C.I.

is as good, at least, as any other article on the market for certain special purposes, and infinitely superior for common everyday use.

3. He takes the attitude that he offers nothing new. This is a very important point, because, if established, it cuts the ground from under almost every argument so far brought against him. The point is, that the Tripod is nothing new. The British already have it ready to hand. So far from adopting any new system, they have only to take the perfectly serviceable tools they possess from the national tool-chest and use them properly. Nothing new, no change, no confusion, no upsetting of people or of existing customs and trade habits—is that *nothing?* But nothing new. A new idea perhaps; and new light on an old and well-tried system, established in Britain 20 centuries at least. No more.

4. Finally, the author takes the position, as yet unassailed, that the new idea, new light, or new-old theory, however it may be named, renders everything which has gone before obsolete and out of date. That is, no stale argument or threadbare theory has any chance unless it is refurbished, and perhaps reforged, to meet the new conditions.

The above may be summed up in a few lines: (i) There is no need to repeat to the author what he knows already; (ii) keep the arguments to actual weights, measures, and currency, and their utility in trade, commerce, and engineering; (iii) prove, if possible, that the author's theory is original, and not as ancient as Assyria and Egypt, Nineveh, Babylon, and the Great Pyramid; or (iv) prove otherwise that the new idea, although so ancient, in no way concerns the Metric System, or detracts from its importance and interest.

The term "British trade" in the title is to be taken in its widest possible sense as including every human transaction in the Empire which can, by any stretch of imagination, be regarded as "sale" or "barter." It brings in, in this way, the affairs of probably every man and woman and child old enough to buy a packet of sweets.

If some catastrophe removed all that appertained to weights, measures, and currency from this planet, not the standards only, but *everything*, how would mankind set about their renewal? That is a question which should not

be overlooked in any argument, because one answer undeniably might refer to democracy and its obligations. No solution which did not as carefully provide for the needs of the small men as those of the great men ought to stand any chance of acceptance. Can any modern civilised man assert the contrary? It may be assumed, therefore, that an international system of weights and measures ought to serve all men, not a minority, however important, not even a majority. If bread tickets are necessary for the existence of a nation, is it enough to see that the majority is fed? Must the minority go breadless?

Another important consideration, the outcome indeed of the last paragraph, is contained in the question: Should a system of weights and measures be purely decimal or should it afford an opening for the employment also of vulgar fractions, and if so, to what extent? This is not merely a matter of opinion; the answer ought to embody personal experience. If even 80 per cent. of men could do with occasional halves, quarters, and eighths, and the system failed to provide for the needs of the remaining 20 per cent., who required sixteenths, and perhaps even smaller non-decimal subdivisions, the system would be defective, and involve serious hardship. The British are so accustomed to determining everything by majorities that they are apt to overlook the fact that a minority might reasonably be the only section of the people affected by a special side issue, the interest of those voting against it being academic. For example, a metre might suit some men, a yard measure others, the foot and inch others again; some people might prefer to divide the inch into thousandths, others into 64ths. Majority voting of the entire assembly in such cases would lead to tyrannies as great as those of any absolute monarch.

Politics have nothing to do with the matter. The intention of giving votes to every man and woman is to give all a voice. The intention is defeated if majorities are allowed to overrule any section of the voices in matters of supreme importance only to the section. All this is not a digression; it is strictly pertinent in any quest for a solution which affects everybody. Professional men are in the habit of consulting clients fully, and do the utmost possible in their interests. In this case the problem is an international

system of weights and measures, and the clients are all humanity. The conclusion is obvious.

It is impossible to say exactly how the ancient scheme came to be framed on the lines on which the author discovered it, but the theory of the Tripod or triple scale in weights and measures is this :—

(*a*) The Polar Axis, about which the whole globe revolves, ought to be the selected earth-line upon which an international scheme should be based.

(*b*) The inch, the most important unit in the whole system, ought to be the 1/1,000,000,000th part of the double Polar Axis, or the 1/500,000,000th part of the single Polar Axis.

(*c*) The chain ought to be 792 of these inches, the number 792 being the least common multiple of all numerals from 2 to 12, with the exception only of 5 and 10, the decimal numbers, provided for in the decimal scale, and 7, the sacred number, little used, and then chiefly to multiply.

(*d*) The numbers representing the decimal, fractional, and duodecimal scales, which would cover all human needs, are 10, 11, and 12.

(*e*) Divide the chain into 10, 11, and 12 parts, and we obtain the double metre, the double yard, and the double duodecimal unit. The metre, the yard, and the duodecimal unit are each the base of a decimal scale, a *système usuel*, and a duodecimal scale respectively.

That is the theory as it presented itself to the author after months of patient digging, and the strangest thing about it is the extraordinary way in which the British system of weights and measures moulds itself into perfect shape round the skeleton. It is said that three coincidences establish a theory. About 20 can be adduced, and are now given in detail. There are probably as many more awaiting discovery.

I. The British inch, so far as we know at present, is less than 1,000th part short of being the 1/500,000,000th part of Earth's Polar Axis of 7,899 miles = 500,480,640 inches.

II. The chain, 792 of these inches, is the ancient Anglo-

Saxon acre-breadth, the furlong of 10 chains being the ancient Anglo-Saxon acre-length.

See the "Encyclopædia Britannica," Vol. XXVIII. (Ed. XI.), page 484, paragraph 13.3, for proof of the existence of the Belgic yard in Britain since the third century at least. Five of these yards made the rod, pole, or perch, and four rods (as now) the chain.

The Belgic yard was therefore the Anglo-Saxon metre, and it appears to have been divided both decimally and into 3 Belgic feet and 36 Belgic inches. There was, at the same time, a true yard of 36 English inches, and 39.60 English inches seem to have made the Belgic yard. It should be noted that the subdivision of the metre into 3 metric feet and 36 metric inches is Napoleon's *système usuel*, introduced into France in 1812 and abolished in 1837. There is nothing new under the sun.

III. We still employ the Belgic yard in the rod, pole, or perch of 5, the chain of 20, and the furlong of 200 metres (British), and in square measure in the rod of 25, the rood of 1,000, and the acre of 4,000 square metres (British). And it will be found that every British unit is derived, more or less directly, from the Belgic yard, which appears indeed to have been the common metre of Europe up to the fifteenth century, so far as can be made out from the records.

IV. We have a metric ton, in the common British ton of 2,240lbs., of the weight of a cubic Belgic yard of water, at or very near the maximum density.

The gallon is based on the summer temperature of water, of which more presently.

V. A flat measuring rod, divided into inches and 10ths on one face and into 10 links on the other face, and 79.2 inches long over all, can be used to subdivide any line of reasonable length into from 2 to 12 parts, except 7 parts only.

VI. A circle, having a diameter of 7 yards, has a circumference of one chain. This proportion is true for all multiples of 7 yards, and the fact is of great value in laying out railway curves.

VII. The term "hundredweight" has puzzled everybody, but now it is known that the ton is metric, and

therefore, as it was in all probability at one time decimally divided, all is explained. A hundredweight of 112lbs. must, in reason, mean a hundred of some well-known ancient weight. What could this be but 100 half-kilograms (British), each equal to 1.12lbs.? It must be remembered that the *système usuel* also made the metric hundredweight 100 half-kilograms, the half-kilogram being the French pound-weight.

VIII. Attention is invited to the strange resemblance between the two systems:—

	Ancient British.	French.
Metre ...	39.6 inches ...	39.37 inches.
Chain ...	20 metres ...	20 metres.
Ton ...	cubic metre ...	cubic metre.
	(of water at or near maximum density).	

IX. If it is thought that our ancestors could not have known of such a thing as maximum density may not the selection of water at or near the freezing point have been due at least to their acquaintance with the expansion of water under the influence of heat? Possessing no thermometers, might they not have elected to take water for measuring purposes always from a stream proceeding from a glacier or a brook filled by melting ice or snow? We can hardly assume that they were totally ignorant of all the common facts of nature; witness, for example, Stonehenge.

X. That a separate duodecimal scale has long been known in the East is proved by the existence of the gudge of 33 inches and its 144th part, the jow, in India.

XI. It is interesting to note that a gudge of 33 inches, divided duodecimally, gives us a unit of 12 avoirdupois ounces, and finally a carat of 3.04 grains, and a lower weight indistinguishable in practice from $\frac{1}{4}$ grain. Compare our troy weight as a vestige of the duodecimal scale in Britain.

XII. The Decimal Association originally took the hand as a symbol of the decimal system. It may also be regarded as a symbol of the perfect system, the 4, 8, and 16 "fingers," the 5, 10, and 20 fingers and thumbs, and including the

wrists, 6, 12, and 24, representing the fractional, the decimal, and the duodecimal scales. The illustration will not appear puerile to those who are acquainted with the part the hand plays in Hindoo mysticism and elsewhere.

XIII. The extraordinary scale of 9 in the British Ale and Beer Measure has puzzled some people, and indeed it would be unintelligible but for the fact that 9 gallons is the practical equivalent of 40 British litres of water, the fluid being expanded to summer heat.

XIV. Similarly, the bushel is the practical equivalent of 36 British litres. There is probably a close connection between XIII. and XIV. in struck and heaped measures which has been lost.

XV. Perhaps the author may be permitted to refer to the Great Pyramid merely from the point of view of its design. Assuming that the building was the work of an intelligent human architect and builder, in whose business weights and measures played an important part, is it not more than a little curious to find that the lengths of the passages show the proportion 10 : 11 : 12, that we find there a Polar inch, a yard, a gudge, a measure of $3\frac{1}{2}$ yards (the radius of a circle with a circumference of a chain), and a measure of 4 metres (158.4 Polar inches)? Also that capacity and weight units seem to be included in its construction, and that the entrance undoubtedly pointed to the Pole Star of that day?

XVI. See Minutes of Proceedings of the Institution of Civil Engineers, Vol. CLXXVII., page 164, for actual tests of ancient Egyptian measures in the British Museum and their extraordinary similarity to our own.

XVII. The universal prevalence of the following units all through the world is very remarkable :—

A measure approximating to a half-metre.
,, ,, foot.
,, ,, bushel.
A weight ,, pound.

Surely this is more than a coincidence?

The fact that the foot is sometimes the third of a metre and at other times nearly the English foot is the more remarkable when Napoleon's *système usuel* is remembered (see II.).

XVIII. The well-known human necessity for being able to work in complete tens, in fractions, and again in complete twelves, would, perhaps, account for a set of three scales in any other science than that of weights and measures, and be accepted as sufficient proof of the Tripod.

XIX. Why should the Decimal Association complain of the "distracting jumble" in British weights and measures but for an instinctive feeling that our weights and measures should be employed with method? We can see very easily now what has happened. The British are making their *système usuel* do the work of all three scales, and are, besides, mixing up different tables, and also decimals with fractions. Rods, instead of being dealt with as 5 metres, are reduced to 16½ feet; bushels are defined in pounds-weight; Troy-weight is occasionally mixed up with Avoirdupois; feet and inches with links; while we have at least three different tons in common use. In the cotton trade, prices are given in pounds-weight and decimals of a penny, when sacks (the tenth of a ton) and florins (the tenth of a pound-sterling) are obviously the best units for the purpose from a wholesale weights and measures point of view. This particular abuse has crept in through the American ton and the cent, and no doubt there is a similar reason for every abuse if its history could be ascertained.

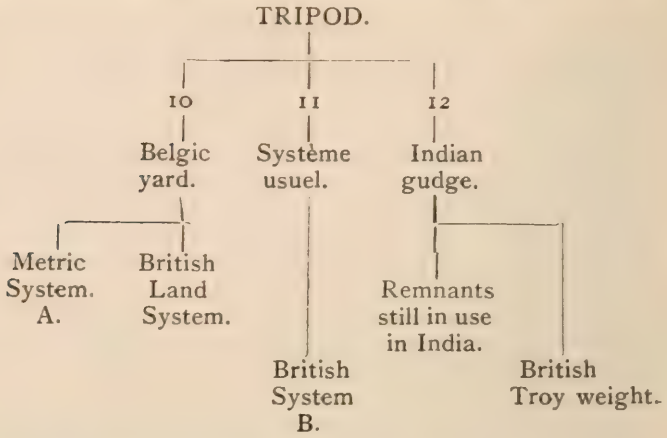
As a coincidence of importance, taken in connection with the above remarks, please note the anxious care bestowed in France upon the purity of metric units, in correct decimal relationship. The metric system would break down in a decade if subjected to the abuses put upon the British system, which has only survived through its superior general fitness and more satisfactory units. "It is usual for building surveyors to measure brickwork by the rod and convert into feet, thus giving themselves unnecessary trouble," says Colonel Sir C. M. Watson in his book. A rod is 5 metres square—that is, 198 inches × 198 inches. The Royal Institute of British Architects lays down for brickwork 4 courses of brick and 4 joints to a foot, a very inconvenient figure, 66 complete courses to a rod of height. Joints in

brickwork are very thin, and might be made wider with advantage. Why not, employing bricks of the present dimensions, run 60 courses to the rod of height and 20½ stretchers and joints to the rod of length? The quotients are 3.3 and 9.66 inches respectively, as against 3 and 9.25 inches now. The regulations at present are not labour-saving (see Molesworth's Pocket Book, 26th Edition, pages 90 to 96). The rod is a convenient unit, and the men understand it. The trouble lies in the mixing up of two sets of scales, which are incompatible. The recognition of the British metre would reconcile all difficulties. There should be a builder's rule in use on every work—a flat rule, 39.6 inches long, divided into 100ths on one face and into inches and 16ths on the other face.

It seems to the author that the difference between the French and British metres represents just the unbridgeable gulf between capital and labour in this country to-day. You cannot stretch 39.37 to 39.60. Both sides must adopt a common metre, and since the educated classes suffer least by a change of this kind, the selected metre should, in this country and Empire, be the British metre. It has been in existence here 20 centuries, and ought not to be required to make way for a system not two centuries old, and at that only an approximate modern substitute for its predecessor.

XX. The author is convinced that the theory of the tripod explains many "mysteries" in trade customs all over Britain. The application of the tripod would shew at once how anomalies could be removed with the least possible disturbance, as by the wand of a magician. He claims the existence of these mysteries collectively as the twentieth coincidence. Otherwise it must be conceded that everything invented in weights and measures before 1790 is lumber, that there was no such thing previously in use as a metre, no *système usuel*, and that historical facts can claim no recognition from philosophy.

The author hopes that in the above he has proved the existence of the tripod in British weights and measures, and that there is very good reason for considering them in the new light. The present position is best explained by diagram :—



The two practical systems to-day, A and B, are locked in deadly conflict, which in the light of the tripod appears uncommonly like aggression on the part of A. If A wins, it means the victory of decimal over vulgar fractions, to the permanent inconvenience and hurt of many millions of human beings. If B won, however, nobody would be hurt, because decimalists would still be free to employ decimals, and might legally employ the British land system and corresponding decimal weights and measures for a great many vital purposes. They would not be prevented from employing decimals in the *système usuel.*

The author thinks it advisable to introduce here the probable fruits of a "victory" of the "British" system (British only in name, being older than Britain and British civilisation by at least 20 centuries).

BRITISH MONEY TABLE.

(a) *Decimal Scale.*

10 florins = 1 pound sterling.

Divide the florin into 100 imaginary cents of account, not coined, for all decimal accounting and decimal quoting.

(b) *Coinage in the* Système Usuel.

12 pence = 1 shilling.
20 shillings = 1 pound sterling.

The penny is divided into halves and quarters, the shilling the same, and the pound into halves, quarters, and eighths. All coins can be used to pay decimal amounts, exactly to sixpence, and within half a farthing for sums less than sixpence. For sums less than threepence a farthing is the practical equivalent of a "cent" (1,000 to a £).

COMMERCIAL LENGTH.

(a) *Decimal Scale.*

5 metres make a rod.

And the metre (39.6 inches) can be divided decimally to any required extent. A metre is 5 links, and a cubic metre of water at or very near the point of maximum density weighs a ton.

(b) *Ordinary Scale, or* Système Usuel.

12 inches = 1 foot.
3 feet = 1 yard.
11 yards = 10 metres (2 rods).

The inch or any unit can be divided fractionally or decimally to any required extent.

TRAVELLERS' LENGTH.

10 chains = 1 furlong.
8 furlongs = 1 mile.

The chain is divided for land surveying into 100 links.

The chain is the Anglo-Saxon acre's-breadth, and the furlong the Anglo-Saxon acre's-length. Ten square chains make an acre = 4,000 square metres.

WEIGHT.

(a) *Decimal Scale.*

10 sacks = 1 ton.

Each sack may be divided decimally into 100 British "kilograms." If the name is not liked, why not call that unit 2.24lbs., a "flint," employing the contraction "fnt.," never likely to be mistaken for "ft."?

(b) *Ordinary Scale, or* Système Usuel.

16 drachms = 1 ounce.
16 ounces = 1 lb.
14 lbs. = 1 stone.
16 stone = 1 sack.
10 sacks = 1 ton.

This is the right scale for retail trade, as it provides for supplies by the week, and for sixteenths in three shifts, for subdivision daily to any required extent.

The sack is also divided into halves, called cwt., meaning a hundredweight of 100 British half-kilograms, or half-flints; and a cwt. is divided into 4 quarters, each of 2 stone, or halves of quarters.

CAPACITY.

(a) *Decimal Scale.*

The theory is the cubic metre of pure water divided into 1,000 litres. In practice the water at 4°C. contained in a British litre is raised in temperature to summer heat, about 62°F., and bulked at that point in the gallon measure. The cube of 39.6 inches = 62,100 c. ins. very nearly. Divide by 1,000, thus obtaining 62.1 c. ins. per theoretical litre. The theoretical gallon $= \frac{62.1 \times 40}{9} = 6.9 \times 40$ = 276 c. ins. at 4°C., expanded to 62°F.

	British.
Firkin, 1 × 9 gallons	= 40 litres
Kilderkin, 2 × 9 ,,	= 80 ,,
Barrel, 4 × 9 ,,	= 160 ,,
Hogshead, 6 × 9 ,,	= 240 ,,
Puncheon, 8 × 9 ,,	= 320 ,,
Butt, 12 × 9 ,,	= 480 ,,

(b) *Retail Trade, or* Système Usuel.

4 gills = 1 pint.
2 pints = 1 quart.
4 quarts = 1 gallon.

The gallon being too small for some purposes—

2 gallons = 1 peck.
4 pecks = 1 bushel.

The scale is all halves and quarters. The bushel is 36 British litres as expanded for the gallon.

The above is the essential whole of the author's "new" system, and he trusts that its publication will settle the matter. Beyond the bare proposal to recognise legally the ancient Belgic yard as the British metre, there is nothing new in it, since we still employ the Belgic yard and its metric ton. How can a measure be new when it is still in common use?

The British seem to have retained the correct international metre, having departed very little from the true length. There is historical evidence of this departure in the standard yard of Henry VII., still in existence and apparently .037 inch in excess of the existing yard. The "Encyclopædia Britannica" gives the length of the Belgic yard as 39.66 inches. The French seem to have lost the Belgic yard, and to have made a mistake in endeavouring to reconstruct it. But there is little doubt that both French and British systems, and their *systèmes usuels*, are derived directly from the ancient Tripod.

There does not seem to be very much more to say. The author desires to restrict discussion, as already stated, to essentials, merely to save time. He hopes that everybody desiring to take part in it will not enter as a partisan for this system or for that, but will bring, in particular, facts which will throw further light on the tripod itself and its effects on our trade customs and methods as they exist to-day, with proposals for improvements, not new systems. We know all there is to be said in favour of the metric system, and unless there is anything *new*, can perhaps dispense with mention of it.

It has been the recognised usage to greet any opponent of the metric system who does not admit that the metre of 39.37 inches is infallible with derisive laughter. Laughter is an excellent thing in its way, but it is hardly argument. Again, at "Decimal" meetings it has been very common to ridicule the British system and its units, employing expressions which are hardly courteous, and generally unscientific. We have been told the yard is the length of a king's arm (and a wonderful-looking object he must have been if the statement is correct!), that a foot is the length of some remarkable human foot, and so on. The time for all that sort of thing is past. The question now is: How reconcile metre and yard in an *Entente Cordiale?*

APPENDIX.

As definite points to place before the meeting, the author asks :—

(*a*) Is it possible to restrict the use of the metric system as an international standard for pure science?

(*b*) Is it possible to make the British decimal system (as shown in the preceding paper) the international standard for trade, commerce, and engineering, that is, for applied science?

(*c*) Ought not the British *système usuel* (see the preceding tables) be permitted, by international agreement, respectful treatment by other nations, to be used legally as desired in any foreign country, even a metric country, by arrangement between contracting parties? This seems to be bare reciprocity in return for the legal recognition of the metric system in the British Empire.

(*d*) The question of an international currency is outside the range of practical politics at present. But it may be remarked that, with the introduction of a metre of 39.6 inches in trade, commerce and engineering, there is no reason why there should not be *one* coin (of about the value of two shillings in every country) of standard and equal weight and fineness, to be minted and used in every nation, even if it is not internationally current.

The following references are given as forming an important supplement to "British Trade and the Metric System":—

The Surveyor [see correspondence columns, 1916, October 13th; and 1917, January 19th, February 2nd, April 27th, May 4th and 18th, July 6th and 20th].

The Monthly Review (the official organ of the Inc. Soc. of Inspectors of Weights and Measures) [1917, July and September].

Indian Engineering has the sole claim to the first publication of the discovery of the Tripod, 1908 to 1910. The above paper presents the Proof.

ADDENDA.

The following remarks were interpolated at various places in the foregoing Paper:—

The subject is so vast, I am compelled to assume that everybody here has some knowledge of my book and of the references on page 15 of the pamphlet copy of my Paper. I assume also that the case for the Metric System is well known.

This Paper is the proof of the existence of a Tripod in British Weights and Measures, and also the proof of what I call the Theory of the Tripod. You will no doubt visualise the tripod as a stand with three legs supporting a theodolite or level or a delicate instrument of precision of the kind, and you will not be wrong. The term "tripod" is applied, in my book, in a collective sense, to the three scales, (1) decimal, (2) ordinary or fractional, and (3) duodecimal, in any complete system of weights and measures, such as the British system really is, all three scales being commensurate, and having one common base in the so-called Gunter's chain. Since, by comparison, a purely decimal system, such as the Metric System, is one-legged, a triple system possessing the utility and stability of a tripod, the reason for the name is self-evident.

I would like you to look at the diagram at the top of page 10 of the pamphlet. The correct tripod is derived from Earth's Polar Axis, in the manner explained on page 4 of the pamphlet.

There must be no confusion of thought between mere decimalisation and the metric system. A true metric system is always one of the scales in any tripod. As it happens we have before us to-night no less than three tripods:—The first is the theoretically correct tripod; the second is the existing British tripod based on a metre of 39.6 inches; the third might be a French tripod, if the other two scales, based upon a metre of 39.37 inches, were added to the metric system.

So far indeed as internationality is concerned, probably less than 8 per cent. (according to calculations based on the trade returns) of all our business transactions, in this

country, relate to metric countries; the rest are all carried out in common British units.

I have tried to shew you something of the national treasure we possess in British weights, measures and currency, and what we stand inevitably to lose by a change to compulsory metric system and decimal coinage. I estimate the average annual cost at 50 millions of pounds sterling for the first ten years after the proposed change (a total of 500 millions). The Decimal Association asserts that the cost will be trifling, and covered many times by the gain to the Empire. I reserve my data until the Association publishes its own estimate in full detail, as it *should* do.

The British position is a very strong one and may be summarised thus:—

1. We actually possess, without change, confusion, or cost, two thoroughly efficient scales, as you will see from pages 10, 11 and 12 of the pamphlet. The one is metric, based on a metre of 39.6 inches, which is a more correct earth measure than the French metre. The other is commensurate with our metric scale and is derived from it. We can, when we please, without confusion and at little cost, add the third or duodecimal scale, equally commensurate, and derived also from the decimal scale.

2. The theory of the Tripod puts us into touch at once with the metric system; and similarly, the British decimal system puts the users of the metric system into touch with the British system. The whole world can utilise the constants, formulæ and designs of all countries in a way hitherto beset with alarming arrays of numerals, but now cleared of all difficulty. It is to this extraordinary advantage, in particular to ourselves, I would invite your close attention to-night. The metric system has become, through the Tripod, an integral part of the British system, and this is as it should be, because the two systems are actually blood brothers, fashioned in the same womb.

Let me beg of you to suspend prejudice. This is no toy, no fad, no crank idea, I am presenting to you to-night, but a theory established by over 40 centuries of experience and practice. I do not want you to accept my bare assertions in any particular. Work them out and prove them for yourselves in your own businesses and professions, and the more you do so the better I shall be pleased. The yard has every whit as good and scientific a right to exist as the

metre, since all scientific difficulties are swept away by the theory of the Tripod, which absorbs the metric theory. The question can now be viewed in correct perspective. The business practical man need not disturb himself any more with theoretical considerations, or be afraid of being thought ignorant of science. So far as he is concerned there is no longer any science, and he can decide for himself on the plain issues he finds in his own business, from day to day.

I should like to explain the meaning in my mind of the term " masses " as employed in these remarks. Every man, when he condescends to small transactions, merges himself in the " masses "; see the definition of " British Trade " at the bottom of page 2 of the pamphlet.

In politics, in the past, the few have dominated the many; and, in the present, the many are supposed, by some method of counting noses, to dominate the few; but the ideal of the Tripod is higher still, and I think the goal of the mental worker is that of the Tripod. In my opinion the only durable solutions of human problems are those which leave behind them no unprovided-for section of humanity, no outraged or plundered minority, no submerged tenth. I think this high ideal is attained in our existing British weights, measures and currency, to a very remarkable and successful degree. The system is not to blame if it is neither used properly nor taught intelligently.

The link in the British land system gives us the British metre of 5 links, or 39.6 inches, the theoretical length (agreeing with the standard yard of Henry VII.) being very nearly 39.64 inches. We hardly use our decimal scale, and the duodecimal scale still less. The second, or middle scale, which I call the fractional scale, is a popular working compromise in vulgar fractions between decimals and duodecimals, a practical medium for translating thought into action. Common sense suggests that we should use the decimal scale in decimal calculations, and the duodecimal scale with duodenary notation for duodecimals. The fractional scale ought to be reserved for practical everyday uses, involving simple calculations. The employment of three scales in the manner described seems more scientific than using one scale exclusively for every purpose. The possession of a fractional scale leaves the " masses " free to use it as best serves their requirements, while the two " scientific " scales would meet every other need.

Write down, for instance, as follows:—

£ = 1,000 mils.
2s. = 100 ,,
1s. = 50 ,,
6d. = 25 ,,

Say, for sums over 3d. add 1 to convert farthings into mils; deduct 1 to turn mils into farthings. Below 3d., the farthing = mil.

Examples:—

£5.637 = £5 12s. 9d.
£9 17s. 10¾d. = £9.895.
£9 18s. 0d. = £9.900.

I submit that the British coinage as it stands is a perfect working compromise between decimals, duodecimals and vulgar fractions. Down to sixpence the decimal and fractional scales are identical. Sixpence is the practical limit between large and small transactions, so the scales differ below this, but to the smallest possible extent, and with obvious fair play in favour of the small men, the masses of the people. With little practice it is the easiest thing in the world to convert decimals into coinage, and *vice versâ*, correct to half a farthing. The practical application is plain, it is easy to keep books and accounts in decimals of a £, and to quote to foreigners and to deal with them, in florins and decimals. Will anybody contend that in large transactions a possible error of a farthing in results is material? Do not many large firms, even now, make a clean sweep of farthings, and work to the nearest penny?

A purely decimal coinage is advocated. That is, we are urged to abolish the (*b*) money table in exclusive favour of (*a*). I think it will be impossible to get English people to drop the name "farthing," so the immediate effect of the alteration would be a new money table:—

4 farthings = 1 penny = 0.96d.
12½ pennies = 1 shilling.
20 shillings = £1.

I ask you how would you be better off for the ridiculous new relationship of 12½? But this is only a beginning.

The new penny will be 0.96 of an existing penny, so that small dealers would have three courses open to them, either to alter the pennyworths, or to lose 4 per cent. in coin, or to charge more. The next trade coin will be the 5-mil piece = 1.20d. So we must assume that the small dealer

will be tempted to charge 5 mils for a pennyworth. We certainly cannot expect him to lose 4 per cent. on each transaction; and a reduction so trifling as 4 per cent. on small quantities is a matter more for a laboratory than a retail shop or a coster's barrow. First of all we upset the small consumer by altering his money standards of value. Then we try to compel the small dealer to become an unwilling philanthropist, or to change his customary methods of making up pennyworths, or to cheat. Please remember that however prices may rise and fall, the pennyworth usually remains, in the process, the purchaser's standard of quantity. Here we shall be trying to change two standards together, the penny and the pennyworth. I speak, of course, of the pennyworth as it may be when the new penny puts in an appearance. Due notice of the change being given, the juggling for profit may be even greater.

Eventually the new penny must become the five-mil coin, and this is what decimalists are working for. What the corresponding pennyworth may be, may be debated, but most men of the world will probably agree with me that whatever happens to the coinage, the dealer will not lose, nor will he make any trade change to his own disadvantage.

This certainty of a rise in retail values is a thing quite apart from the wonderful help a fractional coinage is, in rapid calculation, to the small men, concerned in more than 90 per cent. of the daily business of the country. Fractional coinage enables the small trader to dispense with a clerk; it saves a clerk's time in reckoning; it aids the small consumer to check his bills, etc., without pencil and paper. All this indeed is so well known that I can only suppose that the gentlemen who demand a decimal coinage are not acquainted with the decimal scale of the two sets of tables presented to you. I hope these remarks may lead them to study and reconsider their position. Personally I think our money table the best and most practical in the world, having tested it, by actual experience, with fractional Indian coinage, and decimal French and Italian coinage. You see how easily, in our currency, we can convert decimals into coinage, and *vice versâ*, and yet retain the free use of vulgar fractions? In what other system do we find the same convenience?

Eleven yards is the equivalent of ten French metres, plus $2\frac{1}{4}$ inches, or one nail. The difference is 6 millimetres on a French metre. We possess that decimal ideal, a metric

ton, which we can divide into 1,000 British kilograms for foreign trade, as we divide it into 2,240 lbs. for home trade. The difference in the kilogs. is as 224: 220, less than 2 per cent. I would have you note here that decimal advocates seem to think a difference of 4 per cent. on a penny coin would have no effect on prices, so that differences of 0.6 per cent. in lengths, and say 2 per cent. on weights, and about the same on capacity, must, by decimalist argument, be immaterial. And, arguing the other way about, it must be a more serious matter to adopt a decimal coinage as proposed than to adopt the metric system.

I want to know if, as decimalists claim, the differences do not matter, why we cannot trade in British decimal units as they are doing in metric countries? What is there to prevent the foreign standard of British length being 11 yards divided decimally? What prevents the sale abroad of 400 British metres of cloth, say, at 5.5 florins the metre, the equivalent there of 10s. the yard? The manufacturer gets his price on 440 yards and loses nothing; the retailer gets his profit and loses nothing; and the customer gets good measure and loses nothing. Even if several middlemen come between, it makes no difference. Suppose the foreign retailer sells in French metres, who is the loser thereby? May we not sell beer in France in 9-gallon casks as 40 British litres? The retailer gets 40.89 French litres, which he of course pays for in full, but you may be sure he will not lose thereby. And so with every other unit. Would not all this be merely a form of standardisation with high and low limits, the kind of thing that merchants have done many times in the past without particularising the process?

Regarding imports from metric countries, I think I am right in stating, that the metric system was legalised in this country in furtherance of a Free Trade policy, in order to facilitate the entry of metric goods. Materials in bulk can be retailed in British standard units, but there are some things which cannot be so retailed, except at inconvenience and loss, which, in this case, fall on the British consumer. Since the Tripod can be applied to any metre, we might solve the problem by permitting certain specified and plainly marked metric goods to be sold in reduced weight and measure in tables (*b*), that is, tables (*b*) co-ordinated to a 39.37 inch metre. The arrangement would save much trouble and confusion, and if strictly limited by law, need

not lead to fraud. I believe some goods are already dealt with in some such fashion. It is proposed to make marks of origin compulsory on all goods, British and foreign. The metric system, employed as above, would be, in itself, one distinctive mark of origin, and might be made helpful to our good friends the Allies, by restricting such sales to metric goods manufactured entirely in their countries in return for like consideration for the B.D.S.

Let us consider the effect of a compulsory metric system in this country. On the principle of beginning by keeping to existing units as closely as possible, and to the present names, you would have a new mile of ten reduced furlongs, each of 10 French 20-metre chains, with a new acre, a new rood, and a new rod, pole, or perch, all based on the French metre of 39.37 inches. You would get a new pound weight of 1 1/10lb., and a new ounce of $1\frac{3}{4}$oz., and use the gramme for everything else. You would get a 50 litre new bushel, and a corresponding 10 gallon cask, the gallon being 5 litres. The immediate result would be the abolition of our tables (*b*), with which we are thoroughly well acquainted, and a modification of tables (*a*) beyond recognition. Further, if you dared to employ tables (*b*), whether reduced to the French metre or not, you would be fined and imprisoned, since decimal systems would stand no nonsense of that kind!

And then your troubles would not be over. The new arrangement would be an offence against metric purity, because twos would be employed as well as tens in multiplication and subdivision to get the principal units. It would not be long before we were forced to adopt "nothing but tens." Changing the vital national standards of a people is a business, on no account, in modern times, to be undertaken, if it can possibly be avoided. In our case there is no justification for even one change; and we should make two changes, possibly three.

The attention of architects and engineers is invited to the possibilities in the Tripod. A design, for instance, has to be got out for execution in Paris. The whole of the data, with specifications and standards, can be stated at sight as B.D.S. units. The designs may then be got out in feet and inches, with English constants and formulæ. Or, if it is desired to employ French constants, etc., the drawings can be prepared in B.D.S. units. The designer and the draughtsman will, at least, understand clearly what

they are doing. When the project is completed, the designs have to be dimensioned entirely in B.D.S. units, and as a precaution a scale should be laid down on each sheet. When removed from the boards, the sheets will shrink a little to about the correct metric scale. The specifications would likewise be got out in B.D.S. units. The whole of the documents would then go to France for erection in the metric system. If we desired to employ French designs, etc., in this country, the thing is just as easy. The drawings, etc., however, would have to be dimensioned in feet and inches instead of B.D.S. units, that is all. There is no limit to what can be done in this way. You can design anything, even ships; and adapt English designs to the Continent, just as easily.

Let me put the matter in another way. In the metric system you have a purely decimal scale, which resembles a suite of three beautifully furnished and splendid rooms, with the doors and windows of two of them bricked up and plastered over. In the British system you have one scale with which you can take reasonable liberties in the pursuit of profit and business, and two scientific scales which can be made as accurate and unchanging as the metric system. You can use the two learned scales in office work, and in intricate calculations, to any extent desired, the one acting as a check on the other, if you wish. You disturb nobody, you worry nobody, you distress nobody. The brain of the nation is in touch with all others, inside and outside our boundaries. I do not want to press the point, but I think even electrical engineers might discover the advantages of working in a decimal scale readily convertible into feet, inches, pounds, and so on, or of working in duodenary notation in a duodecimal scale, with results stated in duodecimal units in decimal notation at sight.

I recommend every engineer and architect to calculate some of the formulæ and constants he most frequently uses in the three scales of the British Tripod, and especially to do this with metric constants. Dropping awkward fractions, he will be astonished at the convenience of the results. For example, 40 cubic feet make a ton of shipping. In either B.D.S. or metric system, the practical equivalent is 900 kilogs. to the cubic metre. Again, if a cubic metre (French or British) weighs one metric ton, the equivalent for a cubic yard is 15 cwts. = $\frac{3}{4}$ ton. The error in each case is negligible. If desired, the results can be corrected,

saving the trouble of wading through terrible arrays of figures in calculation.

You will ask me why we need an eleven scale at all, and why we need work in a ten scale or a twelve scale and convert results into an eleven scale, when we might divide the same metre fractionally and duodecimally as well as decimally. The thing has been done in the past, and has never endured. I have here two rules, the one 39.6 inches in length, the other 36 inches. I happen to be a tall man, with a stretch of 6ft. 1½in., but I cannot handle the 39.6 inch measure freely. Most men and women in the factories and shops average in stretch 5ft. oin. to 5ft. 9in., and a measure of 36 inches is the longest they can conveniently work with. If we divided a metre decimally and fractionally, we should have to employ half metres of say 20 inches, and two-thirds metres of say 26½ inches, instead of two-foot and three-foot rules as now, wasting time and possibly making mistakes. I do not say a full metre could not be used in suitable circumstances; I assert that it is not a convenient measure for ordinary manual labour, doing the bulk of the work in this country. That is one only of many good reasons, which I have no time to give now.

I suggest to you that unsound laws have had more to do with losses in trade than wrong methods, themselves too often the outcome of bad national management and policy, and that wrong methods account for the balance. For example, the metric system was legalised in this country without the precaution of arranging for its practical working, and it was admitted without bargaining for reciprocity for our own weights and measures. According to the Decimal Association, armies of clerks have had to be employed in British business houses and in the Customs to deal with metric goods. No foreign country has afforded similar facilities for British goods, or we should not be urged to quote to the foreigner in his own units and currency. So, in effect, we lost export trade through lack of reciprocity, and home trade by the bounty which we, as a matter of fact, have accorded to the metric system. I believe that Germans and Austrians benefited principally, and not our friends.

I am aware that business and professional men, as a matter of principle, avoid politics, but if laws passed by politicians affect business in this way, what alternative have we but to take a hand in law-making? What about an Emigration-within-the-Empire Bill which would leave the alien invasion uncontrolled; or a Coal Economy Bill which

might allow of foreign exploitation of our coal fields as before, or perhaps in an increasing degree; or an Electoral Reform Bill, in which, while purely party considerations receive anxious care, there is no provision for special business or professional direct representation?

The real reason, I think, for decimal coinage being pressed upon us, is, that it would accustom us to change, merely for the sake of change. It would make the teaching of decimals essential in all schools, and this would prepare the way for a further change. My own idea is that education should fit the need in the simplest and easiest manner. The intelligence and capacity of every person has a limit, and it should be the business of education firstly to develop these qualities in each individual to the highest possible pitch, without unnecessary frills, and secondly, to provide the necessary mental and moral equipment, without lumber, for that individual's successful future. It may not be possible to predict the exact place any human being is going to occupy, but it certainly ought to be possible to determine with reasonable accuracy the limitations of individual brain power and capacity, and provide accordingly. If some people find vulgar fractions better than decimals, why trouble them with what they are never likely willingly to use, or with that which, if they did, would be used indifferently? This country once gloried in being able to turn out the best and best-paid men in the world for any job, whether a navvy's or an Empire-maker's. Are we to abandon this high ideal in favour of universal mediocrity, and must democracy stand like stagnant water in a slimy pool at one dead level?

DISCUSSION.

The PRESIDENT said it was impossible not to recognise in Mr. Phillips an enthusiast for British weights and measures. He had rather cut the ground from under their feet by suggesting that the discussion should be confined to ignoring the French metric system entirely, but he thought that members would prefer to discuss both systems.

Mr. EWART S. ANDREWS, B.Sc., M.C.I., said that although he had been extremely interested in the historical references in the Paper, the arguments put forward by the author had not at all convinced him that the decimal system was not in every respect preferable to the incongruous system proposed in the Paper. He admired the trenchant style of the author, but the system seemed to be based on many

assumptions with which he (the speaker) disagreed. The Paper stated that "If A (the metric system) wins it means the victory of decimal over vulgar fractions to the permanent inconvenience and hurt of many millions of human beings." He personally maintained, however, that if the converse were the case it would mean the inconvenience and hurt of more millions of human beings and therefore he was strongly opposed to the vulgar fraction becoming universal. The reason why we found it difficult to appreciate the decimal system in this country was that we had inherited generations of up-bringing upon fractions. The decimal system was not really taught in our schools. Students were brought up on fractions and when their minds were sufficiently confused, the decimal system was introduced as a kind of interesting alternative. Engineering students were notoriously backward in calculations and in mathematical reasoning for the reason he had mentioned. Most English people who understood decimals did not think in them. It seemed to him to be a hopeless policy to say that because generations had wallowed in ignorance the existing generation should do the same. He agreed with the author that we should benefit by the wisdom of the ancients, but we should not slavishly follow their errors, and he was absolutely convinced that the decimal system was the one upon which the greatest national efficiency would be based. He had spoken principally of the decimal system because that was what should be kept in mind. He strongly and firmly believed that we should produce better engineers if their education was based on the decimal system instead of its being introduced in an indirect way; the point was to think in decimals. He was not in the least interested in the fact that the metre had been incorrectly calculated; that was merely a matter of academic interest. The standard length was the length between two given marks maintained in a laboratory or bureau of standards and it did not matter how it came about, so long as it was a convenient and useful standard and so long as the system derived from it was based upon the decimal system. He had no objection to the adoption of the metric system and he was not keenly in favour of it; it was in use over a very fair area of the world and it would be very well that we should gradually educate ourselves to its use, but the thing he was strongly in favour of was the decimal system.

Mr. Barton said that Australia was full of admiration of Great Britain because of what it tolerated and could

still survive under. He would not touch on the metric system because he had been asked not to do so, but he could not help feeling that in Great Britain we endured many things simply because we would not change. Australia very properly thought Great Britain should change. She asked Great Britain to change because she had seen the errors of the old system and she had sent her Premiers over here to ask us to change, and if we refused, some day Australia would change in spite of Great Britain, because she respected her children. She thought of her brains that were being wasted at present at school. This was a very serious thing. It was a question of thinking clearly, and whether we should absorb more items in our system of weights and measures or simplify it. Mr. Phillips had asked if it were possible to restrict the metric system to science, that was, for the educated people. The point was, could we improve our own system? He did not think it was worth while improving and he did not think it was advisable or possible to restrict the metric system to the educated classes. It implied that they were to try to do what the priests in Egypt did—keep the masses in such condition that they could not use their brains, in order that the educated classes might control them. He had visited some of the large engineering shops in Birmingham and Coventry, places where he expected to find the strongest opposition to the decimal system, but he found in a number of those works that the system was used every day in their drawings. The metric system was used for all the linear measurements and the British measurements for all the bolt holes and rivet holes. The system was used without the slightest trouble or difficulty. The extraordinary thing was that people could make themselves believe almost anything. A prominent electrical engineer, Col. Crompton, once said at the Institution of Electrical Engineers that the British working man was essentially a binary calculator, but in the same speech he remarked that the success of the British engineering industry was due to the sub-division of the inch into one thousand parts. The two things were absolutely incompatible. He was a very poor mathematician, but many were the same. He did not learn his weights and measures, but he was glad of it because he was able instead to learn two languages.

Mr. G. Moore, F.S.S., who represented the British Weights and Measures Association and also the American Weights and Measures Association, referring to Mr.

Barton's admiration for Great Britain, said he hoped it would be even greater before he went back to Australia, not because we had adopted the metric system, but because we should have shewn Mr. Barton that there was more in the British system than he had at present grasped. At one time he (the speaker) was a decimal man. He had given lectures in favour of the decimal system, but it occurred to him one day that if that go-ahead country America, with a hundred years' experience of decimal coinage, had not learned by that time the advantage of universal decimals there must be some reason. With that thought in his mind he took the trouble and went to the expense of going to America to find out why they had not adopted the metric system. Whilst in America he became an anti-decimalist. The experience he gained and the information he got from such men as Dr. Colman, Messrs. Sellers, Brown and Sharp, Warner and Swasey, and others of the leading engineers in America shewed him why they kept to British weights and measures. He then went to France, Germany, Sweden, and some other continental countries to find out whether the reports we had of the use in these countries of the metric system were based on practice or on theory. His suspicions were confirmed that the metric system was used largely on paper because he found whole industries in France—and they existed to-day—that did not use the metric system at all. They followed the old system of the French inch divided into 12ths and if they wanted something finer they divided again into 12 points. He did not want his audience to accept that because he said it, but the French Minister of Commerce, in April, 1906, sent out a circular to the French Chambers of Commerce asking them to use their influence with their members and compel them to use the metric system. He (the speaker) accepted an invitation to give, under the auspices of the American Chamber of Commerce, an address in Paris against the metric system. The chairman of that meeting was the managing director of a large engineering works doing Government work, and employing as he was bound to do the metric system; but at the close of the address that gentleman, knowing both the decimal and the duodecimal systems, said that the American and British system was preferable for general engineering purposes, and for general manufacturing purposes. That was said in Paris in 1908. There were, of course, many people who asked why great nations like America and Great Britain did not make the change,

but it would be easy to demonstrate, if there was time, that there is something in the British system which did not appear on the surface and which is only found out when a man begins to do things. One proof of that was, that if a joiner who was a metric man worked with a foot divided into ten against another joiner working with the British foot, the man working with the latter would turn out 15 per cent. more work than the other man. Thus, after all it came to a question of economical working. We must have in this country that system which would enable us to do work of the highest possible character at the least possible expense and in the least possible time. The British Weights and Measures Association had had such men on the Council as the late Sir John Wolfe Barry and Prof. S. P. Thompson and at present had Sir Archibald Denny of Dumbarton, the eminent shipbuilder. The objects of the British Weights and Measures Association and the American Institute of Weights and Measures were not to prevent the use of decimals where they were better than any other kind of fraction for calculation, but they stoutly opposed compulsory decimals when other divisions suited the work in hand better.

Mr. G. McLean Gibson, M.C.I., speaking as one who had met a large number of North Country junior technical school students, said he must differ from Mr. Andrews in regard to such students not understanding decimals thoroughly. These boys learned them thoroughly and understood them very much better than he did himself. In fact, they almost thought in logarithms. They immediately turned things into logs. if they wanted the square or the square root of anything and they were quite capable in the mathematical line.

Mr. H. Kempton Dyson, M.C.I., thought the author had made a practical suggestion in asking that we should have a British metre. The fact that it would diverge somewhat from the continental or metric metre did not seem to him to matter very much. At present there were two systems in vogue by which the bulk of the trade of the world was carried on, viz., the metric system and the British system. It was true that the greater part of the trade of the world was done by Great Britain and America, both of which used the British system and it might be argued that instead of these countries adopting the continental system, the continent should adopt theirs, but he did not think that would be a practical thing to suggest. The practical thing

to do was what the author had suggested, viz., that by adding one unit we had a *via media* by which we could reconcile the continental and our own systems. In this matter he was inclined to say that although the scientific men had been educated they had not been educated quite enough. They had not been trained to use with any ease the duodecimal system. He did not see why, because we had a decimal system, we should use that to the extent of ignoring the old vulgar fraction system or the duodecimal system. It seemed quite possible to educate our students in the future to use with ease the duodecimal system. The author had made some very practical suggestions which appealed to him as regards the use of a British metric system in the making of plans and calculations in the translation from French and German text books into English measures. If we had a British metre there would be great advantages in having a système usuel, which could be used in ordinary mental arithmetic calculations and in having a system of very great value scientifically if properly developed, viz., the duodecimal system.

Mr. PHILLIPS, replying to the discussion, remarked that Mr. Dyson was the only speaker who had grasped the principle of the Tripod, namely, the satisfaction of the need of "every man," the aim of wise legislation of true democracy. Mr. Barton's objection that three scales might introduce class distinctions was based upon misapprehension, since every man would be free to select the scale necessary for the work in hand, and the brain worker or merchant would, in this respect, be on the same footing as the manual labourer or the trader. Mr. Phillips thanked his supporters in the discussion, and was particularly pleased to see Mr. Moore. If his hearers wished to understand the principle of the Tripod, it would be necessary to study the matter from every point of view. To do the right thing by humanity was to provide a complete and commensurate scheme to facilitate working in decimals, duodecimals and vulgar fractions, and this the Tripod did. Oppression and war could only be ended by a policy of universal consideration and complete conciliation, and this the Tripod did in weights and measures. The Tripod, therefore, served as a model for all legislation based on mutual goodwill and forbearance.

The PRESIDENT, in proposing a hearty vote of thanks to Mr. Phillips, said there was a great deal of antagonism between the advocates of the decimal system and the frac-

tional system. There was a great deal to be said for both sides and for this reason they were extremely grateful to the author for reading his Paper.

The vote of thanks having been cordially responded to the meeting then terminated.

The following correspondence was received for publication:—

HOVE,
28th Jan., 1918.

The Secretary,

The Concrete Institute.

DEAR SIR,—I write to thank the Concrete Institute, through you, their Secretary, for your kindness to me the other evening in giving me so patient and prolonged a hearing.

To complete your records I add overleaf my concluding remarks. I have already sent you a record of my remarks, introducing and explaining the paper. I practically read the whole, and would be glad if in any publication of the same nothing were left out.

With renewed assurances of my appreciation of your kindness,

I am, Dear Sir,
Yours truly,
(Signed) E. A. W. PHILLIPS.

P.S.—Will you kindly include "Indian Engineering" and the "Outfitter" in your Press notices and much oblige?—E. A. W. P.

Page 15 *of pamphlet, add at end*:—

"The Outfitter," 20th October, 3rd November, 10th November and (supplement) 17th November, 1917.

I conclude by expressing my deepest gratitude to "Indian Engineering" and the Concrete Institute for publishing my discovery and the proof thereof. I am also deeply obliged to all the Editors who have granted me space in their columns, and am indebted to you all for a patient hearing.

From A. O. Collard, F.R.I.B.A., Architect and Surveyor :—

25th January, 1918.

The Secretary, Concrete Institute,
Denison House, Westminster, S.W.1.

BRITISH TRADE AND THE METRIC SYSTEM.

DEAR SIR,—Though the subject may not be so vitally important to our profession as to people in commerce, it seems clear that indirectly all will feel the benefit of the proposed change.

It is obvious that international inter-communication is ever increasing, nations are consequently becoming more dependent on each other, so the refusal to adopt the metric system must hamper our trade.

I have read somewhere that Mr. Balfour is credited with saying that obliging us to use the old weights and measures is equivalent to making people avoid the roads and forcing them to jump over hedges and ditches. This is an apt illustration.

So far as architects are specially concerned, the pros and cons are fairly summarised as follows, I think :—

REASONS FOR.

1. No compound arithmetic would be needed in calculations and there would be no complicated tables to remember or be kept for reference.

2. The systematic relation of all the various units of measure and calculation.

3. One decimally divided scale would take the place of the numerous scales by which architects now make and read their drawings.

4. The metric system being international, there would no longer be the difficulty of converting foreign drawings into English dimensions, and foreigners would be saved the same real trouble when we send our own drawings abroad.

REASONS AGAINST.

1. The temporary inconvenience of scrapping the present scales, rules and various tables of weights and measures and the cost of new scales.

2. The difficulty of persuading builders and workmen to understand and use the metric system.

No doubt your lecturer alluded to the also proposed adoption of a decimal system of coinage, which seems to me to be of almost prior importance. In fact the dual

systems of decimal coinage and weights and measures are hardly separable.

Yours faithfully,

A. O. COLLARD.

SEVENTY-EIGHTH ORDINARY GENERAL MEETING,

THURSDAY, FEBRUARY 28TH, 1918.

THE SEVENTY-EIGHTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held on Thursday, February 28th, 1918, Mr. F. E. WENTWORTH-SHEILDS, President, in the Chair.

THE PRESIDENT submitted the following as recommended for election and they were approved by the votes of the meeting:—

ASSOCIATE-MEMBERS.

Mr. HAROLD WILMOT BARRAS, M.B.E., Civil Engineer, East Molesey.

Mr. HAROLD WILLIAM COURT, Engineer's Assistant, Chief Engineer's Office, Port of London Authority.

ASSOCIATE.

Mr. JAMES WOOD, Scarborough.

THE PRESIDENT announced that the following gentleman had been elected a Student:—

Mr. ARTHUR BENJAMIN NEWBY, London.

THE PRESIDENT: "Although our attendance is rather small, much smaller than it ought to be in view of the importance of the subject, I will call on Mr. Marsh to read his Paper."

Mr. CHARLES F. MARSH, M.Inst.C.E., V.P.C.I., then read the following Paper:—

Criticisms of the London County Council Regulations relating to Reinforced Concrete.

The regulations recently issued by the London County Council, relating to the use of reinforced concrete in building construction, are the first of any importance in this country and will doubtless be used as a basis for similar regulations throughout the provinces.

It would therefore appear advisable that the provisions of the regulations should be carefully considered and discussed by a body such as the Concrete Institute, before they become stereotyped, in order that other local authorities, before adopting them as a basis for local regulations, may be in a position to form a considered judgment as to what portions require amendment.

It is not supposed that this paper deals with all matters open to dispute, nor that the opinions expressed are necessarily those which will ultimately be found to be justified after criticism and examination; but it is strongly urged that an open discussion of the regulations by the members of this Institute will be of considerable utility in helping forward the proper employment of this useful and interesting method of construction and must be of the greatest assistance to those revising or framing such regulations.

Regulations governing the use of reinforced concrete or any other material should be framed in such a manner as will give the greatest scope to the development of the material with all necessary safeguards, but without placing undue restrictions upon its use, such as must tend to prevent its employment in suitable cases.

It is recognised that the drafting of a complete system of regulations is an arduous and difficult matter and that there must be a tendency for personal and collective opinions and prejudices (based on insufficient or unjustifiable premises) becoming incorporated. There must also be a temptation to err on the restrictive side and to introduce arbitrary and unwarrantable clauses. The recognition of the difficulties and temptations which must beset the framers of regulations does not justify the withholding of fair and legitimate criticism, and it is hoped that the person or persons responsible for the final drafting of any of the criticised paragraphs will accept such criticism with an open mind and receptive intelligence.

It is assumed that those members who are interested in the subject of the paper will have provided themselves with a copy of the L.C.C. Regulations, as it is proposed to refer to the various paragraphs by their numbers, without quoting them at length.

It is also very possible that other paragraphs than those dealt with in the paper may be referred to during the discussion.

Paragraph 2 was, it is believed, inserted to permit the construction of reinforced concrete floors, such as were permitted before the passing of the London County Council (General Powers) Act, 1909, without being subject to the special regulations. The paragraph as drafted does not, in the author's opinion, make this clear.

Paragraph 18 does not state the plane to which the angle of dispersion may extend. It is believed that it was the intention that this plane should be the axis of the main tensile reinforcing bars.

Paragraph 19 does not, in the author's opinion, give sufficient relief, and it is contended that the rate of reduction should be 10%, not 5%. The Joint Committee on Reinforced Concrete, instituted by the Royal Institute of British Architects, in their Second Report, recommended a reduction of 10%, after careful consideration, and it is possible that the main reason for the limit of 5% in the L.C.C. Regulations is the fact that this limit is incorporated in the regulations for steel frame construction. If this is the case, it is contended that uniformity is an insufficient

reason for limiting the relief in the case of the reinforced concrete regulations, if 10% is a safe allowance.

The limitation of the reduction to 50% is believed to be reasonable.

The meaning of the paragraph would be made clearer if it was stated as follows:—

"For the purpose of calculating the total load to be carried on foundations, pillars, and walls in buildings of more than two storeys in height the following allowances may be made:—

"For the loading on the supports to the roof and top floor allow the full load.

"For the loading on the supports to the second floor below the roof allow in addition to the above the full dead load of that floor plus 90% of its superimposed loading.

"For the loading on the supports to the third floor below the roof allow in addition to the above the full dead load of that floor plus 80% of its superimposed loading.

"And so on, the superimposed loading on each lower floor being reduced by increments of 10% till the reduction amounts to 50%.

"For all lower floors the reduction of their superimposed loading shall be a constant amount of 50%."

Paragraph 28 limits the length of a cantilever to five times the effective depth at the bearing, but it is not clear why the length should not be allowed to vary with the actual maximum tensile or compressive stresses, as is permitted in the case of a beam, under paragraph 27.

Paragraphs 31, 35 and 38, when read together will allow, in the case of a continuous beam over a wide support, an effective span equal to the clear span plus the effective depth of the beam or slab, provided the sectional area of steel, required at the end of the effective span, is carried across the centre of the support.

It is suggested that the regulations would be improved if a special paragraph were devoted to this case, which is by no means an unusual one.

It is also suggested that the definition of the effective span in paragraph 35 does not agree with that in paragraph 31.

Paragraphs 42 (*a*) and (*b*), 159 and 162 will be con-

sidered together as they refer to the strengths of the various concrete mixtures.

The proportions of the ingredients of the several mixtures given in the tables to paragraphs 42 (*a*) and 159 are unusual and there does not appear to be any adequate reason for their use in preference to the usual method of description.

If there is any useful purpose in the new basis of proportionment, it would still be desirable that the ordinary description for the various mixtures should be also given, *i.e.*, in the table to paragraph 42 (*a*), 1 : $1\frac{2}{3}$: $3\frac{1}{3}$ in the second column, 1 : $1\frac{1}{3}$: $2\frac{2}{3}$ in the third column, and 1 : 1 : 2 in the last column.

The same criticism applies wherever the proportions are referred to in the other paragraphs of the regulations.

There appears no sufficient justification for equations such as those laid down under paragraphs 42 (*b*) and 162 for assessing the strengths of the various mixtures of concrete and on which the strengths of the mixtures specially referred to in paragraphs 42 (*a*) and 159 are based.

The author contends that the use of these equations does not allow sufficient strength for mixtures stronger than 1 : 2 : 4.

He also contends that the strength of a mixture does not vary directly with the ratio of the volume of sand + the volume of large aggregate to the volume of cement, and that regulations such as these should not lay down such a law without ample and sufficient justification.

It will be noticed that, in the mixtures specially referred to in the regulations, the volume of sand is always half that of the coarse material.

Under these conditions and under the further conditions imposed under paragraphs 146, 147, 150, 151, 153 and 154, with respect to the quality and grading of the aggregates, there is evidence from various experiments and tests that the strength of the various mixtures varies closely with the ratio of the volume of cement to the volume of cement + the volume of sand in the concrete, as is shewn by Fig. 1.

The inequalities of such a heterogeneous material as concrete, the strength of which must, in the nature of the

case, be influenced by many varying conditions, render it somewhat difficult to assert confidently any definite law as to its relative strength with variously proportioned ingredients.

Comparative tests, however, certainly appear to indicate that, for any constant ratio of the volume of sand to the volume of coarse aggregate such as 1 to 2 and with a coarse aggregate of approximately the same grading of sizes, and of material of approximately the same compressi-

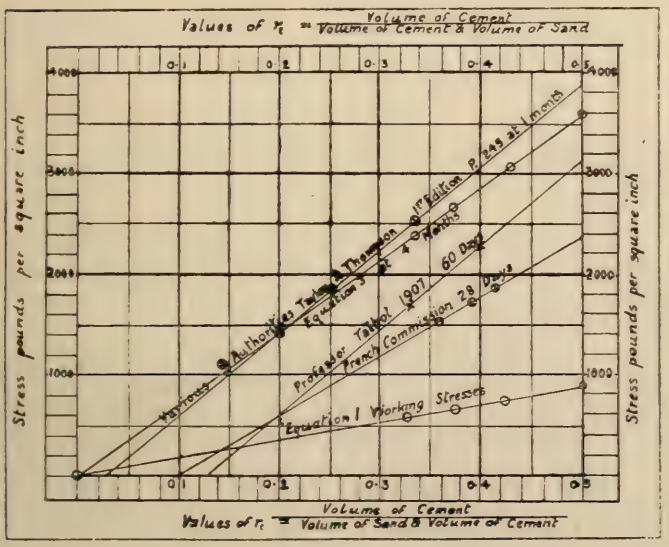

Values of r_c = Volume of Cement / Volume of Cement & Volume of Sand
Stress pounds per square inch
Stress pounds per square inch
Volume of Cement
Values of r_c = Volume of Sand & Volume of Cement
Equation 1 Working Stresses
Professor Talbot 1907
Trench Commission 28 Days
Equation 3
Thompson 1st Edition P. 249 at 1 month
60 Days
Authorities Tests
Various

FIG. 1.

bility, the compressive strength of various mixtures varies directly with the ratio of the volume of cement to the volume of cement + the volume of sand in the mixture, as is shewn by diagram, Fig. 1.

This result would lead to the conclusion that the compressive strength of such a concrete depended on the strength of the mixture of sand and cement, or, in other words, on the strength of the mortar of which the concrete is composed.

Such a conclusion is strengthened if we admit the proposition that, in actual fact, all failures under whatever conditions they occur, are ultimately failures under tensile stress, since it is obvious under such conditions that the compressive strength of a concrete can only be due to the tensile resistance of the mortar of which it is composed.

Many will doubtless have already arrived at this conclusion, but to some it may appear to require something more than a mere statement to establish such a proposition.

If the behaviour of a specimen is examined, when tested to failure under compression, it will be found that when the specimen is short in proportion to its least diameter, the first indication of failure is a bulging out of the sides.

This bulging is followed, not by a pulverisation in a longitudinal direction, but by the bursting off of prisms from the sides, due to the tensile tearing apart on inclined planes.

This form of failure is frequently referred to as a shearing failure, but so-called shearing failures are in reality caused, not by the cutting of planes of cleavage, but by their tearing apart.

It is evident that, if the failure of a member under compression is in reality due to a tensile rupture, the strength of a concrete specimen can only be controlled by the tensile strength of the mortar of which it is composed.

It may be contended that, since it is well known that the compressive resistance of concretes is frequently greater than that of the mortar of which they are composed, the failure under compression cannot be due to the tensile resistance of the mortar; but the greater resistance under compression of the concrete is really due to the fact that the shortening of the concrete is relatively less than that of the mortar under equal loadings, due to the presence of the larger aggregate and the consequent reduction of the lateral expansion.

Experiments on the deformation of mortar and concrete specimens would undoubtedly prove the truth of this statement.

If the specimen tested under compression is relatively long in proportion to its least diameter, lateral flexure takes

place and the final failure is due to the bending of the specimen, causing a tensile rupture.

All failures under compression, even those in members subjected to flexure and which can resist all tendencies to first failure, due to direct or diagonal tension, shew the same indications of being in reality tensile failures.

The failure on the compression side of a beam occurs, not by the pulverisation of the material, but by a flaking off or parting of the fibres.

That so-called shear failures are in reality tensile failures is also obvious from their character, and in the case of reinforced concrete this is now generally admitted.

A true punching shear very rarely occurs, and even in this case the failure is probably really due to the tearing apart of the several fibres.

A failure by torsion is clearly due to the tensile rupture of the material.

The failure of a laterally confined material under compression is a further proof of the original proposition, as such a failure always occurs, not by pulverisation, but if the length of the specimen is comparatively short in comparison to its least diameter, by a bursting of the lateral support, followed by or rather together with (as the two failures are practically instantaneous) a failure of the material itself of exactly the same nature as that which the unbound material would shew under compression.

If the lateral support on a short column were sufficiently strong, such a member would have an infinite bearing capacity.

What would happen under an infinite load with a lateral support of infinite strength is an interesting speculation, but such a test might result in the discovery of the fourth dimension which must be the embodiment of the infinite, producing something denser than any solid, yet more attenuated than any gas.

If the length of a hooped specimen is relatively great compared with its least diameter, flexure will occur and the final failure will be due to a tensile fracture, but much later than in the case of an unbound specimen of the same material, since the shortening will be relatively greater.

It is contended that true compressive pulverisation

never occurs and that even final pulverisation under pressure percussion or attrition is really due to the bursting of the particles of the material under tensile strain.

It is suggested that equations in the form of

$$1{,}800r_c = c \quad . \quad . \quad . \quad . \quad (1)$$

should be adopted under paragraph 42 (*b*), and

$$5{,}400r_c = u_1 \quad . \quad . \quad . \quad . \quad (2)$$
$$7{,}200r_c = u_4 \quad . \quad . \quad . \quad . \quad (3)$$

under paragraph 162,

r_c being the ratio of the volume of cement to the volume of cement + the volume of sand in the concrete under consideration.

It may be contended that the curves in Fig. 1 would indicate that the above equations should be in the form

$$ar_c - b = c, \; u_1 \text{ or } u_4 \text{ as the case may be}$$

where *a* and *b* are constants for any constant ratio between the volume of large and small aggregate and with a large aggregate of approximately the same grading and compressibility. The value of the allowable working stress, however, is all that really concerns us, and if it is admitted that the working stress of 600lbs. per square inch for 1 : 2 : 4 concrete allowed by the L.C.C. regulations is a fair one, an equation in the form $ar_c - b = c$, which gave this value for 1 : 2 : 4 concrete, would give relatively higher values for concretes stronger than 1 : 2 : 4 than the equation proposed by the author.

Table I. gives the values of c, u_1 and u_4 for the various mixtures given in the regulations derived from equations (1), (2) and (3).

TABLE I.

Proportions of mixture.	1 : 2 : 4	1 : $1\frac{2}{3}$: $3\frac{1}{3}$	1 : $1\frac{1}{3}$: $2\frac{2}{3}$	1 : 1 : 2
Value of r_c	0.33	0.375	0.4285	0.5
,, c	600	675	770	900
,, u_1	1,800	2,025	2,210	2,700
,, u_4	2,400	2,700	3,080	3,600

If the mixtures are selected giving regular increases in strength the particulars are given in Table II.

TABLE II.

Value of u_4	2400	2700	3000	3300	3600
,, u_1	1800	2050	2250	2475	2700
,, c	600	675	750	825	900
Proportion of mixture	1:2:4	1:1.66:2.33	1:1.4:2.8	1:1.18:2.36	1:1:2
Value of r_c	0.33	0.375	0.4167	0.45835	0.5
Lbs. of cement per cubic foot of sand in mixture ...	45	54	64½	84½	90

With respect to the relation of u_1 to u_4, or the strength of concrete at one month to its strength at 4 months, so far as can be reasonably deduced from the study of various tests, there appear sufficient grounds to conclude that u_1 should be in the close neighbourhood of $\frac{3}{4}\ u_4$. There is no constant relationship between the values of u_1 and u_4 under the L.C.C. regulations.

The Special Committee on Reinforced Concrete of the American Society of Civil Engineers, in their final report, give the values for the strength of concretes at an age of 28 days in cylinders 8 inches diameter and 16 inches long as shewn in Table III., to which have been added the values according to the L.C.C. regulations and the author's equation (2), assuming the volume of the large aggregate to be twice that of the sand.

TABLE III.

Volumetric proportions of cement to combined volume of coarse and fine aggregate measured separately.	1 : 3	1 : 4½	1 : 6
Granite or trap rock ...	3,300	2,800	2,200
Gravel and hard limestone or sandstone	3,000	2,500	2,000
Soft limestone or sandstone	2,200	1,800	1,500
L.C.C. regulations	2,200	1,900	1,600
By equation (2)	2,700	2,160	1,800

Paragraph 150 of the L.C.C. regulations would bring the coarse aggregate under one of the first two definitions.

The American Committee specify that the proportioning shall be effected so as to secure the greatest possible density of aggregate; and such a method of proportioning, although more troublesome and requiring more intelligent supervision, would give the greatest possible strength, but this would not be sufficient to account for the difference of strength between the values given by the American Committee and those according to the L.C.C. regulations, whereas the values given by equation (2) appear to be sufficiently conservative.

It may be noticed that the values, according to the American Committee, for gravel, etc., vary according to an equation similar to that of the L.C.C. regulations, being

$$4{,}000 - 333V = u_1$$

but this is probably a coincidence as the other values do not follow a similar law.

The values given by the French Government Commission for gravel concretes at 28 days are shewn in Table IV. These values vary directly with the ratio of the volume of cement to the volume of cement + the volume of sand and consequently follow the law advocated by the author.

The strengths and stresses according to the L.C.C., the author, and the American Committee have been included in Table IV.

It will be noticed that the volume of large aggregate is twice that of the sand in the concretes recommended by the French Commission.

The French Commission allow a working stress of 0.28 the strengths at 90 days, which are about $1\frac{1}{2}$ times those at 28 days, consequently they allow about 0.42 of the strengths at 28 days.

The L.C.C. strengths at 28 days do not bear a fixed relation to that at 4 months, but they vary from $\frac{2}{3}$ in the case of 1 : 2 : 4 concrete to $^{11}/_{15}$ in the case of 1 : 1 : 2 concrete. The working stress (*c*) [paragraph 42 (*a*)] is consequently from 0.375 to 0.34 of the strength at 28 days.

According to the author's formulæ the working stress (*c*) [equation (1)] is 0.33 of the strength at 28 days.

TABLE IV.

Volumetric proportions.	1 : 1.75 : 3.5		1 : 1.56 : 3.12		1 : 1.37 : 2.75	
	Compressive strength at 28 days. lbs. per sq. in.	Compressive working stress. lbs. per sq. inch.	Compressive strength at 28 days. lbs. per sq. in.	Compressive working stress. lbs. per sq. in.	Compressive strength at 28 days. lbs. per sq. in.	Compressive working stress. lbs. per sq. in.
French Commission ...	1,520	638	1,706	717	1,890	798
L.C.C. equations, paragraphs 162 and 42 (*b*) ...	1,750	638	1,864	666	1,976	694
Author's equations (2) and (1)	1,963	654	2,106	702	2,279	760
American Committee's equation, $4{,}000 - 333V = u_1$ and with working stress of $0.325\ u_1$ ...	2,250	731	2,440	793	2,628	854

The American Committee allow for members under flexure 0.325 of the strength at 28 days.

Speaking generally with respect to the L.C.C. regulations as to the strength of concretes, it is contended that there is no true basis for the equations given, that the strengths for concretes stronger than 1 : 2 : 4 are considerably below their proper values and that the universal adoption of these rules would greatly prejudice the use of the stronger mixtures.

It is further contended that equations as suggested by the author may with safety be adopted for assessing the strength of various mixtures, when the volume of sand is one half that of the coarse aggregate and the grading and quality of the aggregates is that specified in the L.C.C. regulations.

In the table under paragraph 42 (*a*) the values for the safe shearing resistance would follow those for safe compressive resistance, being $^1/_{10}$th the latter in all cases.

There is, in the author's opinion, no justification or necessity for two values for the grip or adhesion stresses and he would suggest that the value of 100lbs. per square inch equally covers both cases.

The "adhesive" resistance, when there is also an anchorage, is an indeterminate quantity, and, with effective anchorage of any sort, it cannot be doubted that stresses very much higher than 100lbs. per square inch would produce no injury.

Paragraph 43 allows a working tensile stress of 16,000lbs. per square inch on mild steel without regard to its use in direct or diagonal tension.

The limit of 16,000 is, in the author's opinion, somewhat high for use in calculations with respect to diagonal tension, as in this case the actual stress on the reinforcement cannot be accurately determined.

It is suggested that for diagonal tension calculations, $\frac{3}{4}$ the stress allowed for direct tension is sufficient, which would reduce the working stress for diagonal tension to 12,000lbs. per square inch for mild steel.

For compressive reinforcements in hooped columns the limit of working stress should be half the stress at yield point, which would be about 16,000lbs. per square inch for mild steel.

It is suggested that when high tensile steel is used the allowable working stress might be increased to 20,000lbs. per square inch either in direct or diagonal tension and that when used as compressive reinforcement in hooped columns the limit of working stress should be half the stress at the yield point.

It is also suggested that specification requirements for high tensile steels should be included in all reinforced concrete regulations.

In paragraph 48 (*b*), the length of the straight part of the hook beyond the end of the curve is required for the purely practical purpose of allowing a length to grip the

bar when bending. Such a provision does not appear to be a subject for regulation.

Paragraph 54 imposes values for the coefficient "m," as shown in Table V., based on the working stresses given in paragraph 42 (*a*) and on the stresses suggested by the author as obtained from equation (1).

TABLE V.

Proportions of mixture.	Value of "m."	
	Based on stresses as given in paragraph 42 (*a*).	Based on stresses as given by equation (1).
1 : 2 : 4	15	15
1 : $1\frac{2}{3}$: $3\frac{1}{3}$	13.846	13.33
1 : $1\frac{1}{3}$: $2\frac{2}{3}$	12.857	11.688
1 : 1 : 2	12	10

For hooped columns the value of "m" would vary with the form and spacing of the lateral bindings and with the ratio of the volume of the lateral *bindings* to the volume of the hooped core.

This regulation must have the effect of considerably adding to the complexity of the calculations and in the case of hooped columns will render the design a most tedious and troublesome matter.

The modulus of elasticity of concrete in compression is an extremely variable quantity depending on many conditions and much difference of opinion still exists as to its value. There are obvious reasons of expediency for allowing the coefficient "m" to be constant for all mixtures ordinarily used for reinforced concrete, and, at any rate, its assumed value should, in every case, be a whole number.

It is quite true that the modulus of elasticity of concrete in compression, under like conditions, increases with the strength of the mixture, but the limits of its variation would not, in any material degree, endanger any structures, the design of which was made on the assumption that the value

of "m" was 15 for concretes ranging in strength from 1 : 2 : 4 to 1 : 1 : 2, and such an assumption must considerably simplify the necessary calculations.

From the study of many tests the author has come to the conclusion that the probable value of "m," based on the value of the moduli of elasticity of the concrete and steel, for 1 : 2 : 4 concrete at a stress of 600lbs. per square inch is in the neighbourhood of 17.5.

The modulus of elasticity of concrete, used in assessing the value for "m," should be its instantaneous value at the working (or even a somewhat higher) stress, whereas most authorities give the initial value. Since the stress-strain curve for concrete under compression is a parabolic curve, as shewn in Fig. 2, it is evident that the instantaneous modulus of elasticity, which is given by the tangent to the curve for any particular stress, must become less as the stress becomes greater and consequently the value of "m" must increase with the stress.

When deciding on the value to be assumed for the coefficient "m," it must also be borne in mind that there are other factors to be considered as well as the moduli of elasticity of the concrete and steel. The effect of loading and unloading is one such factor. When a member is loaded, both the concrete and steel in compression must contract, and, on removing the load, the steel, being truly elastic, tends to resume its original length, but the concrete takes a permanent set even under very small loads. The consequence is that after unloading, the concrete is left under tensile stress and the steel under compressive stress. On again loading the member the initial tension on the concrete must be overcome before it suffers compressive stress, while the steel, being already under compression, will be subject to a higher relative compressive stress than under the first loading. This action has an effect similar to the increase of the coefficient "m."

It is also evident that the shrinkage of the concrete when hardening must produce exactly the same effect as loading and unloading the member.

It is extremely probable that these two factors will cause a material increase to the theoretical value of "m."

Professor Talbot, of the University of Illinois, from careful experiments on hooped columns, without longitudinal reinforcement, 10 feet high and having cores 12 inches diameter, found that the stress-strain curve for hooped concrete is much the same in character as that of plain concrete, up to a loading which would cause failure of plain concrete.

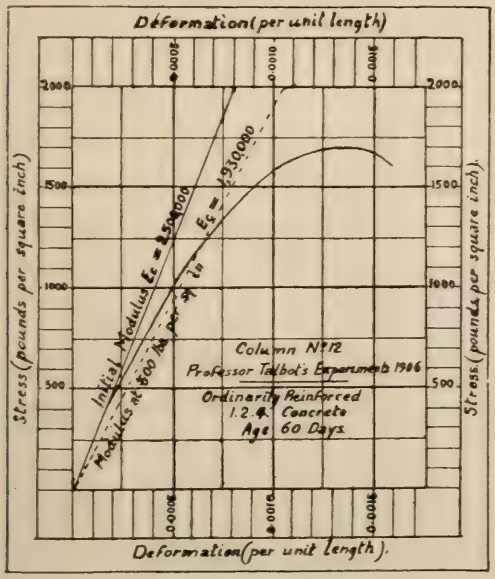


FIG. 2.

Fig. 3 shews the stress-strain curves for two typical hooped columns, tested by Professor Talbot, one of the stiffest and one of the most yielding columns being selected as illustrations.

It will be seen that the stiffness of these columns differed considerably, probably due to some variation in the fabrication, as the percentage of hooping is about the same in each case.

It will also be noticed that the initial modulus of elasticity for column No. 181 was less than that for the typical

ordinarily reinforced column shewn in Fig. 2, whereas the initial modulus for column No. 183 was greater. A curve lying midway between those for columns Nos. 181 and 183 (Fig. 3) would shew somewhat greater stiffness at the earlier stages, but less stiffness during the later stages than the curve Fig. 2, and the initial modulus of elasticity would be somewhat greater than that for the curve Fig. 2.

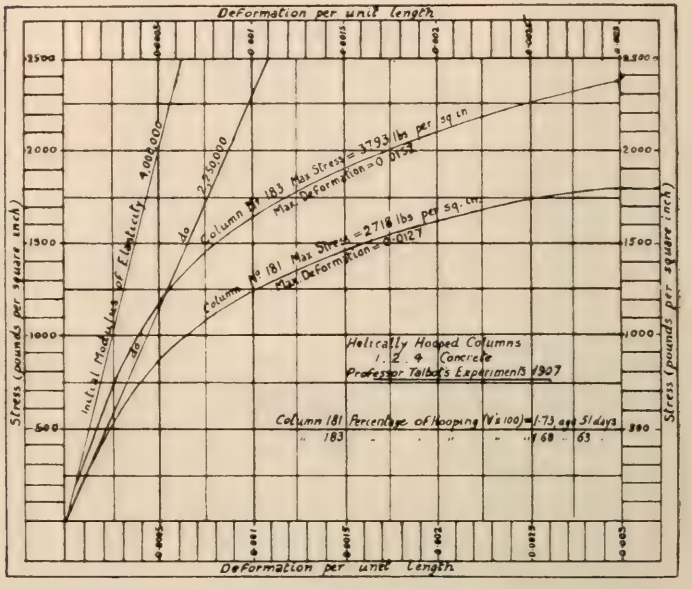

Deformation per unit length
Stress (pounds per square inch)
Initial Modulus of Elasticity
4,000,000
2,250,000
Column Nº 183 Max. Stress = 3793 lbs per sq. in.
Max. Deformation = 0.0152
Column Nº 181 Max. Stress = 2718 lbs per sq. in.
Max. Deformation = 0.0127
Helically Hooped Columns
1 . 2 . 4 Concrete
Professor Talbot's Experiments 1907
Column 181 Percentage of Hooping (V's 100) = 1.73 ages 51 days
" 183 " " " = 1.68 " 63 "

FIG. 3.

Professor Talbot states that from the results of his experiments it appears that the initial modulus of elasticity does not vary materially between the ages of 60 and 200 days.

Allowing that the hooping of concrete renders it stiffer, and adopting the stress-strain curve for column No. 183 (Fig. 3), the hooping would cause an increase in the instantaneous modulus of elasticity at any particular stress, with a consequent *decrease* in the value of "m," but the allowance of an increased working stress "i" in the case of hooped concrete would reduce the relative instantaneous

modulus of elasticity to be assumed for hooped members as compared with that assumed for ordinarily reinforced members, with a consequent relative *increase* in the value of "m." In other words, the decrease in the value of "m" which would be due to the presence of hooping, would be counteracted by the increase due to the higher working stress "i."

The instantaneous modulus of elasticity for column No. 183 (Fig. 3) at a stress of 600 lbs. per square inch would be about 2,450,000, but at a stress of about 850 lbs. per square inch it would be reduced to 2,000,000 and have lower values for all higher stresses.

It is contended that there is not sufficient justification for insisting on a varying value for the coefficient "m" decreasing with stronger mixtures and that the value of "m" for use in the design of hooped members need not be less than that used in the design of ordinarily reinforced members. There appears to be no justification whatever for providing that the value of "m" shall be obtained from equations such as those given under paragraph 54, which are based on no recognised data, being purely empirical, and which give values which, in some cases, are not even whole numbers.

It is also contended that since the modulus of elasticity of concrete in compression is, at the best, a doubtful quantity, and as other factors must be taken into account when deciding on the value of "m," a constant value of 15 for this coefficient is quite sufficiently accurate for the purposes of calculation and that the assumption of this constant value is justified, under the circumstances, by the simplification it allows in the necessarily intricate calculations required for the design of reinforced concrete members.

In the case of paragraphs 61 and 62 dealing with the use of compressive reinforcements in beams and similar members, it is extremely doubtful whether the spacing of the anchorage specified in 61 (*b*) is really necessary in the case of rectangular beams, and, in any case, the second proviso, that the anchors shall not be further apart than 16 times the least diameter of the anchored bar, is not justified since the compression bars can never be stressed as highly as ($m \times c$) lbs. per square inch and in the majority of cases will only be stressed to $\frac{2}{3}$ ($m \times c$) or slightly more. (These values are in the case of 1 : 2 : 4 concrete, 9,000 lbs. per square inch and 6,000 lbs. per square inch respectively.)

The anchorage is only required to resist the lateral deflection of the reinforcing bars and the security against this action would, in the author's judgment, be provided by anchorages considerably further apart than the distance insisted on under this regulation.

It is suggested that in rectangular beams the anchorage should not be further apart than 24 times the least diameter of the anchored bar. [See footnote to discussion on par. 62 (*b*), page 18.]

In the case of T-beams the proviso that the spacing of the anchorages shall not exceed the *effective depth* of the beam, might, in the author's opinion, be included, since it ensures a sufficient shearing resistance between the leg and flange of the T-beam, but this is really a proviso to be considered under resistance to shear.

In the author's opinion the resistance of 16,000 lbs. per square inch for a mild steel compressive reinforcement as specified under paragraph 62 is too great and should be reduced to 14,000 lbs. per square inch at the most and a similar reduction be made to the resistance of the tensile reinforcement.

If the true action, in this case, is considered it will be evident that, so long as the concrete and reinforcements act together, the neutral axis will always be above the centre of the depth of the beam and consequently the resistance of the compressive reinforcement must be less than that of the tensile reinforcement and the assumption of equality of the two resistances will in reality necessitate the stressing of the tensile steel above its allowable resistance.

The granting of some relief such as is afforded by paragraph 62 is certainly justified in the author's opinion as it is certain that when compressive reinforcement is employed the resistance to flexure is in fact greater than that allowed for under paragraph 61, but not to the extent allowed under paragraph 62.

The distance apart of the anchorages specified under paragraph 62 (*b*) could, in the author's opinion, be greater than 8 times the least diameter of the anchored bar, as the direct stress on the compressive reinforcement would not cause material lateral deflection with anchors at much greater distances apart.

The limit of 6 inches for the spacing is a very conservative assumption.

The author would suggest that the spacing, in this case, might reasonably be extended to a distance equal to 12 times the least diameter of the anchored bar.*

In paragraph 64 the first alternative appears to be unnecessary and the author fails to see what authority there can be for limiting the shearing resistance to the compressed area of the web, since the shearing resistance must continue from the neutral axis to the surface of the tensile reinforcement in order that this reinforcement may act in the resistance to flexure. In fact the maximum unit shearing stress on the concrete exists from the tensile reinforcement to the

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* Considering the reinforcing bar as an ideal column fixed at the ends and applying Euler's formula for this case, which may be written

$$p = 4\pi^2 E \frac{g^2}{l^2}$$

it is evident that the ideal column may be considered as a short column, or, in other words, it will not fail by flexure until the ratio $\frac{l}{g}$ becomes great enough to cause the stress p given by Euler's formula to be less than the compressive resistance of the material at yield point.

Consequently, for a mild steel bar with a resistance at yield point of 32,000lbs. per square inch and a modulus of elasticity of 30,000,000, the ratio of $\frac{l}{g}$, below which the failure cannot occur by flexure, will be given by Euler's formula, thus :—

$$\left(\frac{l}{g}\right)^2 = \frac{4\pi^2 \times 30{,}000{,}000}{32{,}000} = 37{,}011$$

$$\text{or } \frac{l}{g} = 192.$$

For a round bar $g = \frac{d}{4}$ and for a square bar $g = \frac{d}{3.56}$

Consequently the reinforcing bar, as an ideal column, can be considered as short and cannot fail by flexure until the length exceeds 48 times the diameter in the case of round bars or 54 times the diameter in the case of square bars.

The bar may not be absolutely straight between the anchorages, and therefore it cannot be considered as an ideal column, also the fixing at the anchorages may not be absolutely rigid ; a reduction must therefore be allowed on the theoretical length for a short column. Dividing by a factor of 4, the safe length of a round bar to be considered as a short column will be 12, and that of a square bar will be 12.5, when the stress is the safe working stress of 16,000lbs. per square inch.

It would therefore appear that the distance apart of the anchorages need never be less than 12 times the diameter of the anchored bar, and can exceed this amount when the stress is less than half that at the yield point.

neutral axis and reduces from maximum at the neutral axis to nil at the centre of the compressive resistance.

It would almost seem as if the authorities responsible for the final draft of the regulations assumed that, as the tensile resistance of the concrete is neglected, the diagonal tension could not be resisted by the concrete on the tensile side of the neutral axis, and forgot that the resistance they were providing for under paragraph 64 was the safe maximum unit shearing stress intensity, the value of which can only be legitimately calculated at any vertical section from the equation $S_{max} = \frac{S}{b_r a}$ while an equation in the form $S_{max} = \frac{S}{b_r n}$ has no justification whatever.

There is no theoretical justification for paragraph 65, as if the concrete is able to resist the whole diagonal tension no reinforcement can be necessary. The proviso is in reality unnecessary and should not be a subject for regulation.

It is not suggested that the method of construction referred to is not practically a good one. If, however, 50% of the tensile bars are bent up, the remainder should be carried well over the supports to the beam.

In paragraph 66 it is not clear why, in this case, "d" is substituted for the limit "a" under paragraph 64.

In actual practice it would be very seldom, if ever, that the limit of $\frac{S}{b_r d} = 3$ times the safe shearing stress under regulation 42 (a) would be exceeded and it appears from experiments, carried out on beams reinforced against diagonal tension, that the limit specified is a reasonable one even if "a" were substituted for "d."

The restriction as to spacing of the diagonal tensile reinforcements under paragraph 67 (a), while it complies with the best practice and is certainly advisable in the case of T-beams, does not appear to the author as a justifiable regulation in the case of rectangular beams where the sharp increase in the shear at the plane of junction of the web and a flange does not occur.

It is suggested that the words "or vice versa" should be added to paragraph 69.

The author fails to see the reason for the restriction as to the effective depth of slabs, under paragraph 72, which appears also to be merely an arbitrary ruling.

Provided a floor slab satisfies the regulations as to resistances, cover to reinforcements and relation of depth to span, there appears no reason for placing an arbitrary value on the effective depth.

The note to this paragraph pointing out that in the London County Council area the minimum depth of floor slabs under the principal Acts is 5 inches, indicates the necessity for amending these Acts at as early a date as possible, since the necessity for 5 inch floors throughout any class of building must seriously curtail the economical use of reinforced concrete.

In paragraph 78, dealing with distribution bars, it is not by any means clear how the imposed values have been arrived at. Why, for instance, is the cross sectional area limited to 0.08% of the effective cross sectional area of the slab?

In actual practice it is quite usual to use $\frac{1}{4}$ inch rods spaced 12 to 18 inches apart, according to the circumstances of the case, where there is no actual necessity for a two-way reinforcement.

It is also not at all clear why the diameter of the distributing bars should be limited to at least $^1/_{16}$ the effective depth, nor why the spacing should not be greater than four times the effective depth.

It would, in the author's opinion, be sufficient to specify that in cases where a two-way reinforcement was not theoretically necessary, distribution bars not less than $\frac{1}{4}$ inch diameter should be inserted with a spacing not greater than 18 inches. It is possible that, in framing this clause, there was some confusion between distribution bars and bars to resist shrinkage stresses. In the latter case a reinforcement of not less than, say 0.5, or even 0.33 per

cent. of the gross sectional area of the member and having a mechanical bond, should be placed near the exposed surface and be well distributed.

The width of flange permitted in the calculations for T-beams under paragraph 82 (*a*) and (*c*) is considerably less than has hitherto been admitted to be perfectly safe limits in the best practice and one can see no justification in reducing, without an ample reason, limits which have always proved safe and reliable for conservative design.

Paragraph 82 (*a*) should be $\frac{1}{3}$ effective span of the T-beam and paragraph 82 (*c*) should be 15 times the thickness of the slab.

In paragraph 83 the limiting width might reasonably be increased to at least six times the thickness of the slab. The second proviso might stand, providing the limits under paragraph 82 were increased as suggested.

Paragraphs 87, 88, 113, 116, 117 and 121, shewing methods of calculation, should not, in the author's opinion, form part of the regulations.

Regulations such as these are surely merely intended to provide against improper design or construction of the material covered by the regulations and not as a text book on methods of calculation.

The necessary and also, in the present case, unnecessary restrictions are sufficiently provided for in the general paragraphs of the regulations and the requisite formulæ for use in carrying out the provisions of the regulations should certainly not form a part of the regulations themselves.

If the authority issuing a set of regulations desires to assist the unfortunates who must become subject to their restrictions, this assistance should be added as suggestions in an appendix.

The L.C.C. regulations are, in the author's opinion, unnecessarily restrictive with respect to the design and construction of pillars and struts, and, if they are to be complied with, the use of either ordinarily reinforced or hooped compression members will only be economically possible in rare instances.

The regulations provide that the effective diameter or that to the outside of the outermost longitudinal reinforcement shall be used in all calculations for compression members, whether reinforced in the ordinary way or hooped;

the working stresses being those given in paragraph 42 (*a*) or the increased value "*i*" allowed under regulation 115.

This provision is unnecessarily restrictive on the employment of columns reinforced in the ordinary way and it is strongly urged that the resistance of reinforced concrete compression members of this character should be permitted to be calculated on the outside sectional area with working stresses on the concrete $^{5}/_{6}$ of those given in paragraph 42 (*a*) as altered according to the author's equation (1).

Such a method of calculation for ordinarily reinforced compression members has been the universal practice up to the present and has proved perfectly safe and reliable and there appears no justifiable reason for the restrictions imposed by the L.C.C. regulations.

Table VI. shews comparative strengths and designs of square columns of 1 : 2 : 4 concrete, and a study of this table will shew the effect the L.C.C. regulations will have on the economy of the employment of columns reinforced in the ordinary way.

The restrictions, with respect to the spacing of bindings, imposed under paragraph 105 (*a*) are excessive in the case of ordinarily reinforced columns.

The bindings are in this case mainly required to prevent lateral deflection of the longitudinal bars, and the limits of spacing in the author's opinion might safely be 16 times the diameter of the least longitudinal bar. [See footnote to the discussions on par. 62 (*b*), page 18.]

The restriction of the spacing to $^{6}/_{10}$ the least *effective* diameter of the member is justifiable in the case of hooped members, as in this case the bindings serve as a lateral support to the concrete.

Paragraph 105 (*b*) should merely specify that, in ordinarily reinforced members, the spacing of the lateral bindings shall be half that provided for under paragraph 105 (*a*) for a distance at the ends equal to $1\frac{1}{2}$ times the *outside* diameter.

In the case of a hooped member no such restriction is necessary.

Paragraph 107 should only apply to hooped members, as it is a provision applying to this class only.

It is not clear why, in paragraph 108, the restriction has been enforced, that longitudinal bars shall not be

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SHEWING COMPARATIVE STRENGTHS AND D

Details of column.			Design as suggested in paper allowing resistance of concrete over gross sectional area and working stress on concrete of 5/6 c = 500 lbs. per square inch. Pitch = 16 diam. of longitudinal bar.				Designed according to L.C.C. lations—resistance of concre fined to sectional area o Working stress on concrete c		
Diameter of column.		Diam. of each of four longitudinal rods.	Limiting height for short column 18 x diam of core in feet.	Safe load.	Bindings.		Limiting height for short column 15 x diam. of core in feet.	Safe load.	Bir
Gross.	Core				Pitch	Diam			Pitch
ins.	ins.	ins		lbs.	ins.	ins.		lbs.	ins.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
8	5	$1\frac{5}{16}$	$7\frac{1}{2}$	50,000	15	$\frac{3}{16}$	$6\frac{1}{4}$	36,840	3
12	9	$1\frac{1}{8}$	$13\frac{1}{2}$	100,000	18	$\frac{1}{4}$	$11\frac{1}{4}$	80,640	$4\frac{1}{2}$
15	12	$1\frac{1}{4}$	18	150,000	20	$\frac{1}{4}$	15	128,400	5
18	15	$1\frac{5}{16}$	$22\frac{1}{2}$	200,000	21	$\frac{5}{16}$	$18\frac{3}{4}$	179,520	$8\frac{1}{4}$
20	17	$1\frac{1}{2}$	$25\frac{1}{2}$	250,000	24	$\frac{5}{16}$	$21\frac{1}{4}$	233,640	9
22	19	$1\frac{5}{8}$	$28\frac{1}{2}$	300,000	26	$\frac{5}{16}$	$23\frac{3}{4}$	284,640	10
24	21	$1\frac{11}{16}$	$31\frac{1}{2}$	350,000	27	$\frac{5}{16}$	$26\frac{1}{4}$	340,200	12

Compare column (9) with column (5), columns (10) and (11
compare columns (14) and (15) with columns (7) and (6), co

VI.

OF SQUARE COLUMNS OF 1 : 2 : 4 CONCRETE.

Designed according to L C C. Regulations for safe loads given in column 5 of Table. Resistance of concrete confined to sectional area of core. Working stress on concrete

$$i = 600\,[1 + fs\,V_{-}]$$

with same longitudinal rods as in column 3 of Table.

Safe load.	Bindings.			Diam. of each of four longitudinal rods.	Value of i.	Diameter of column.		Limiting height for short column 15 x diam. of core in feet.
	Percentage of volume of core $V_{-} \times 100$	Diam.	Pitch.		lbs. per square inch.	Core.	Gross.	
lbs.	ins.	ins.	ins.	ins.		ins.	ins.	
(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
50,000	0.75	$\frac{1}{4}$	$0.6d$ $4\frac{1}{4}$	$1\frac{5}{16}$	600	7	10	$8\frac{3}{4}$
100,000	,,	$\frac{3}{8}$	$0.5d$ $5\frac{1}{4}$	$1\frac{1}{8}$	618	$10\frac{1}{2}$	$13\frac{1}{2}$	13
150,000	,,	$\frac{13}{32}$	$0.4d$ $5\frac{1}{4}$	$1\frac{1}{4}$	636	13	16	$16\frac{1}{4}$
200,000	,,	$\frac{13}{32}$	$0.3d$ $4\frac{1}{2}$	$1\frac{5}{16}$	654	$15\frac{1}{4}$	$18\frac{1}{4}$	19
250,000	,,	$\frac{3}{8}$	$0.2d$ $3\frac{1}{4}$	$1\frac{1}{2}$	672	$16\frac{1}{2}$	$19\frac{1}{2}$	$20\frac{1}{2}$
300,000	,,	$\frac{3}{8}$	$0.15d$ $2\frac{3}{4}$	$1\frac{5}{8}$	672	18	21	$22\frac{1}{2}$
350,040	,,	$\frac{3}{8}$	$0.125d$ $2\frac{1}{2}$	$1\frac{11}{16}$	672	20	23	25

columns (6) and (7), and column (8) with column (4) ; also (19) with column (1) and column (20) with column (4).

greater than two inches diameter, as there does not appear any justifiable reason for this limit.

The limitation in paragraph 109 is one that should only apply to hooped members and the limit in this case should, in the author's opinion, be reduced to 0.8 per cent., as this figure has been generally accepted and has proved to be adequate.

The lower limit of ½ inch diameter bars, provided for in paragraph 108, is quite sufficient to cover the control of the sectional area of the longitudinal bars in columns reinforced in the ordinary way.

A statement might be added to paragraph 118 to the effect that intermediate values for the spacing factor may be obtained from the equation $s = 48 - 80\ \frac{p_b}{d}$

Paragraph 119 is, in the author's opinion, an unnecessary restriction on the design of hooped members, and this class only can be affected by this paragraph.

The Second Report of the Joint Committee on Reinforced Concrete, under the auspices of the Royal Institute of British Architects, suggests a limit of $(0.34 + 0.32f)\ u$ which gives $\frac{1}{2}u$ for rectangular laterals, $^{7}/_{12}u$ for independent circular hoops and $\frac{2}{3}u$ for helical bindings—u being the ultimate compressive strength at three months which has values comparable with the four month values of the L.C.C. regulations and equation (3).

The French Government regulations allow $0.6u$ for helical bindings, u being the ultimate compressive strength at three months, which would be equivalent to 2.14 times the working stresses or about 0.9 the compressive strength at 28 days, which value is given in Table IV.

The French Government Commission, having ascertained by experiments that the failure of the outer covering of hooped members occurred at stresses from 0.25 to 0.60 in excess of the ultimate strength of the plain concrete, stated that the limit of $0.6u$ for helical bindings is such that the working stress can never exceed half the stress at which the failure of the outer covering of concrete would commence. As a matter of fact it would be, in most cases, considerably below this limit.

The author suggests that the limitation of $(0.34 + 0.32f)\ u$ given above will be perfectly safe, although somewhat higher than that allowed by the French Government, that for helical bindings being 2.64 times the working stresses given by the equation paragraph 42 (*b*) or by equa-

tion (1) or 0.88 times the compressive strength at 28 days given by equation (2) [see Table IV.].

The limitations on the length of columns and the loading to be allowed on long columns as provided under paragraph 122 are unnecessarily severe.

It is suggested that the limitation for calculation as short columns should be 18 times the least diameter of the core in case of ordinarily reinforced members and 15 times the least diameter of the core in the case of hooped members.

It is well known that the lateral deflection of hooped columns is greater than that of ordinary columns of equal strength and consequently the calculation as short columns should be restricted to a less comparative length for hooped than for ordinarily reinforced members.

Although it is believed that the above limits might with safety be increased to 18 times the least *outside* diameter in the case of ordinary columns and 18 times the least diameter of the core in the case of hooped columns, the possibility of the stripping off of the outer covering of concrete during a fire gives some justification for the lower limits suggested.

It is contended that the imposed coefficients for the reduction of loading on long columns given in the table under paragraph 122 are unnecessary and very restrictive.

It is obvious that the coefficient of reduction for the loading can bear no fixed relation to the ratio of the effective diameter to the virtual length, as it must be dependent on the construction of the column, *i.e.*, the amount and position of the longitudinal reinforcements.

It certainly bears a relation to the ratio of the radius of gyration to the virtual length, but this does not theoretically follow a straight line law, although the coefficient of reduction for the loading would, theoretically, follow such a law in relation to the *square* of the ratio of the radius of gyration to the virtual length.

The decreased loading can be readily calculated with sufficient accuracy by an equation in the form known as Rankine's, which may be written

$$P_{max} = \frac{P}{1 + \frac{ul^2k^2}{\pi^2 Eg^2}} \quad . \quad . \quad . \quad . \quad (4)$$

Where P_{max} = maximum safe loading for the long column.
P = safe loading on a short column of the same construction.
u = ultimate strength of the concrete [u_4, paragraph 159, or equation (3)].
l = actual length of the column.
E = modulus of elasticity.
k^2 having the following values:—

For members fixed as first described in paragraph 124 $k^2 = \frac{1}{4}$.
" " second " " " $k^2 = \frac{1}{2}$.
" " third " " " $k^2 = 1$.
" " fourth " " " $k^2 = 4$.

Substituting in equation (4)

$$g^2 = \frac{\text{moment of inertia of section}}{\text{equivalent area of section}}$$

and $\frac{\pi^2 E}{u_4} = K$ where $E = E_c = \frac{30{,}000{,}000}{m}$

we get

$$P_{max} = \frac{P}{1 + \frac{l^2 k^2}{K\left(\frac{I_c + (m-1)\,I_s}{A + (m-1)\,A_s}\right)}} \quad . \quad . \quad (5)$$

The author would allow A as the *gross* area in the case of ordinarily reinforced members and the *effective* area in the case of hooped members.

Similarly, I_c would be the moment of inertia of the *gross* section of the concrete for ordinarily reinforced members and the moment of inertia of the section of concrete within the core in the case of hooped members.

Table VII. gives the values obtained by the use of equation (5) and from the use of the values allowed under the L.C.C. regulations for square columns reinforced in the ordinary way being 8 inches and 12 inches square outside and of 1 : 2 : 4 concrete, the longitudinal reinforcement being that given in Table VI. The columns are considered as being fixed at the ends and 12 feet and 18 feet high respectively.

TABLE VII.

	Column 8in. x 8in. outside (5in. x 5in. core) reinforced as in Table VI. and of 1 : 2 : 4 concrete, 12 feet high						Column 12in. x 12in. outside (9in. x 9in. core) reinforced as in Table VI. and of 1 : 2 : 4 concrete, 18 feet high.					
	P lbs. (Table VI.)	g inches.	$v = l$ inches.	d inches.	Coefficient of reduction.	P max lbs.	P lbs. (Table VI.)	g inches.	$v = l$ inches.	d inches.	Coefficient of reduction.	P max lbs.
From equation (5)...	50,000	2.2	144	8	0.88	44,000	100,000	3.6	216	12	0.989	98,900
Under L.C.C. Regulations based on ratio $\frac{v}{g}$	36,840	1.79	144		0.21	7,740	80,640	3.31	216		0,55	44,350
Under L.C.C. Regulations based on ratio $\frac{v}{d}$	36,840		144	5	0.08	2,950	80,640		216	9	0.4	32,260

It is contended that the values given by the use of equation (5) are perfectly safe and reliable.

It will be seen from the examination of Table VII. that the employment of the coefficients imposed by the L.C.C. regulations allows very low loadings and that while these regulations are in their present form it is advisable for those who must work under them, and who find it necessary to design a long column, to calculate the loading from the ratio $\frac{v}{g}$ and not that of $\frac{v}{d}$.

The author fervently hopes that the general question of the restrictions imposed by the L.C.C. regulations on the design of compression members will be adequately dealt with during the discussion, as he feels convinced that this section of the regulations should be considerably modified at an early date, if the use of reinforced concrete columns in the County of London is not to be unjustly and severely restricted.

As to the design of hooped members, the author would strongly urge the adoption in regulations of the recommendations contained in the Second Report of the Joint Committee on Reinforced Concrete, under the auspices of the Royal Institute of British Architects, and would draw the attention of members to the Second Report of the Committee of the Institution of Civil Engineers on Reinforced Concrete, which, after the study of a considerable number of experiments on hooped columns, deals with the recommendations of the R.I.B.A. Joint Committee, and while stating their opinion with respect to the employment of a reduced value for the coefficient "m" and making other criticisms, concludes, "On the whole, the formulæ and method of calculation may be said to be satisfactory and can be recommended for use."

In paragraph 180 the author suggests that the mortar mixture should be of the same proportions as the cement and sand in the concrete which is being used.

The limit of temperature specified in paragraph 182 is, in the author's opinion, higher than necessary and he considers that the concreting operations might be allowed to be proceeded with until the temperature fell to 35° or 34° Fahr. without fear of harmful results, as freezing would not actually occur until 32° Fahr.

THE DISCUSSION.

THE PRESIDENT: "This Paper is one that has a great deal more than an academic interest. These criticisms of the L.C.C. regulations are, I suppose, given by Mr. Marsh primarily with a view to promoting economical construction, and I expect if he could give us the relative costs, say, of a warehouse designed under the regulations, and another designed under the regulations revised according to his liking, the difference between the two figures would be astonishing."

SIR HENRY TANNER, C.B., I.S.O., P.-P.C.I.: "I am very pleased to propose a hearty vote of thanks to Mr. Marsh for his Paper. It seems to me it is very important and desirable that a separate Standing Committee should be appointed to bring out all the points which may be raised by general practitioners, so that they could be considered by the L.C.C. in due course, and I have no doubt the Superintending Architect will be very glad to have any suggestions of that kind, so that he can modify his regulations from time to time and bring them up-to-date. These are modern in regard to regulations for concrete, but they are not very modern as regards building and there are many things in them which require to be brought up-to-date. So far as I am concerned, I do not profess to have any theoretical knowledge of reinforced concrete. Although I was Chairman of the Royal Institute of British Architects' Committee and also of the Joint Committee afterwards, my duty consisted in keeping the thing regulated and to get the results out of the members of the Committee, and I think that our First Report and even our Second Report formed the basis of a great deal of what has been done since. However, that is very long ago. We began our labours in 1905, and our First Report was issued in 1907, and things have moved very much since that time. There is, however, one point which struck me very forcibly on several occasions, and that is the factor of safety. It seems to me that with the strength developed in concrete, a factor of safety of 4 is altogether too much, and I think it should be less. I know that structures that have been carried out under me have borne without any deflection very much higher loads than they were estimated

for, and therefore I think there has been some excess of material used in these particular places. I can only say I am very glad Mr. Marsh has brought this matter forward."

Mr. W. G. Perkins, M.C.I. (District Surveyor, Holborn): "I did not come here to-night with the intention of saying very much, because as a District Surveyor I have now to administer these regulations. If I say anything, a note will be taken of it, and it will be brought up against me if I have to take legal proceedings against anyone. Therefore I do not want to say very much. I will just run through the Paper and make a few comments, agreeing or disagreeing with Mr. Marsh and perhaps saying why. On page 2 of the Paper Mr. Marsh refers to paragraph 2 of the regulations, and says he believes it was intended to permit the construction of reinforced floors such as were permitted before the passing of the London County Council (General Powers) Act, 1909, without being subject to the special regulations. I believe that is so. That is the view I adopt, and if a builder wishes to build or construct reinforced concrete floors in my district in a building which is not wholly of reinforced concrete construction, I should permit him to do so under the older regulations of the Act. With regard to paragraph 19, which deals with the percentages which may be deducted from the live loads, I really do not think there is very much in the author's criticism. If we were permitted in this country to erect buildings to the height which is permitted in the United States, there would be a great deal in Mr. Marsh's argument, but the height of buildings here is limited, and any advantage which you might get from this discounting of the live load would not amount to very much. I therefore do not think it is worth troubling about. Mr. Marsh then refers to an apparent discrepancy between regulation 31 and regulation 35. There is a discrepancy there. Paragraph 31 says that the effective span should be taken as the clear span plus the effective depth of the beam or slab or the length between the centres of the supports. You then go to regulation 35, which gives a formula for determining the bending moment, and you are governed by the notation given in that regulation. If you look at the two regulations you will find they do not agree, but I do not think it matters very much, because you are governed by regulation 35, and from that you must obtain your bending moment, and in consequence I do not think you need pay very much attention to regulation 31. Per-

haps Mr. Etchells will put me right on that if he thinks I am wrong."

Mr. Etchells: "The definition in regulation 31 is a regulation. Regulation 35 (*b*) gives *l* as the effective length of the span and refers you back to regulation 31. It might, however, be desirable to emphasize the fact that we are governed by regulation 35."

Mr. Marsh: "That is rather important, because regulation 35 *does* govern you."

Mr. Perkins: "Mr. Marsh then comes to the stresses permitted in concrete by the regulations and says the stresses are not high enough. With regard to that, I would say that when Mr. Marsh is acting for an authority like the Water Board, he can, in carrying out the work, have a competent inspector, and he can have materials of the very best, because apparently money is no object; in fact, he can do everything possible to ensure a perfect concrete being made and used, but when it comes to the District Surveyor, he cannot do that. Nine out of ten large buildings put up in his district are by speculating builders. Many buildings are built by speculating builders, men who are out to make money and who therefore wish to construct in the most economical way. Those are the people we have to legislate for, and I think it is largely for that reason that these comparatively low stresses have been inserted in these regulations."

Mr. Marsh: "The strengths which I consider too low are those for the stronger concretes, and your remarks just as much apply to the 1 :2 :4, which I see no reason to object to. All I say is, put them on the same footing. Why should you guard against the builder in the stronger concretes and not the 1 : 2 : 4?"

Mr. Perkins: "You want to guard against builders of the type I have mentioned because they treat the richer concretes in the same way as the poorer mixtures. When the calculations are brought to us they say, 'We are going to use a certain mixture, one of the richer ones,' but the District Surveyor cannot be always on the job standing by the mixer or the gang of men mixing the concrete to see they put in the proper amount of cement or sand."

Mr. Marsh: "Then provide regulations dealing with the 1 : 2 : 4 concrete as well as everything else."

Mr. Perkins: "That would be the better way, in my opinion, when dealing with regulations governing the building operations of men like the speculating builders. These regulations are provided for such people and not for the architect or the engineer who wishes to construct a building in the best manner. I think Mr. Marsh rather answers his own argument later on when he refers to the inequalities of such a material as concrete."

Mr. Marsh: "That applies to 1 : 2 : 4 as well as to any other. I only say put them all on the same footing."

Mr. Perkins: "You are likely to get these inequalities in all mixtures of concrete, and for that very reason it is desirable you should not go to the high stresses suggested.

Later on Mr. Marsh deals with the value of *m*. I agree with him that in drafting regulations like this the idea should be to keep them as simple as possible. One does not want a series of numbers or numbers entailing decimal points, but a whole number like 15, a round number, because it simplifies the calculations and makes the work very much easier to supervise. Mr. Marsh considers the regulations unnecessarily restrictive with regard to pillars and struts, but if he had seen some of the work that has been commenced in my district I do not think he would have said that. I will give one or two instances. In a building certain building columns were constructed to carry beams having a span of 40ft. These columns were reinforced with six bars and links at close intervals. The work was being done by a well-known contractor, a reinforced concrete specialist, and his method of constructing the columns was to put up his shuttering for the whole height of the column, and he had a group of links at the top. He put in three pails of concrete and then dropped a link; then another three pails of concrete and another link. I objected to this method, and appealed to the Architect and the Clerk of Works—there fortunately was one—who had not objected up to then, and the result was that the whole of the boarding on one side of the mould was stripped off and the concrete was deposited in regular layers and the links inserted at regular intervals.

Supposing the whole column had been constructed in the haphazard way described, a serious accident might have happened. Again, I say the District Surveyor cannot always be there to see that sort of thing, and it is a very good reason why stresses should be kept low.

Another case. In a building of reinforced concrete five storeys high, a pillar at an angle of the building in the basement was cast several inches out of the upright, thus inducing, owing to the eccentric loading, very considerable stresses. These stresses were not provided for in the calculations, and it was only owing to the large bulk of the pillar and the low direct stress that I was able to pass the work.

In the same building the whole of the continuity rods in one of the bays of a floor were bent down immediately over one of the beams instead of at the point of contraflexure. The floor had to carry a super-load of 2cwts. per square foot, partly a live load, and when I objected, the builder said that the bends could soon be put in the proper place. A little later I went to see what had been done, and found that the rods had been straightened and bends made in a new position. That did not do the steel any good; these rods of high carbon steel after having been bent first one way and then another were not adapted to take high stress.

I wish Mr. Marsh had made a few more remarks about the regulations towards the end of the set. I am afraid it is quite impossible for the District Surveyor or any other authority to enforce properly the regulations as regards testing and workmanship. For instance, concrete during dry weather has to be kept damp by means of wet sacking or by watering daily, Sundays and holidays included. Who is to enforce such a regulation as that? I think it is impracticable."

Mr. W. Noble Twelvetrees: "I came here in the hope of listening this evening, but it appears I have unexpectedly to say something, and I shall try to follow the laudable example of Sir Henry Tanner in saying as little as possible. There is, however, one thing I cannot avoid and that is, expressing my personal obligation to the author for his very interesting and useful Paper, and I should like to urge that after this Institute has decided that modifications—and I would say drastic modifications—should be made in the regulations, they will immediately take action. Sir Henry Tanner has made a very practical suggestion to the effect that a Standing Committee of the Concrete Institute should be appointed to go into the whole subject of revising the L.C.C. Regulations. That idea, as a visitor, I heartily support, but it has to be remembered that three other institutions have to be convinced before the L.C.C. can make any movement. Then, I understand, the procedure

is that the L.C.C. have to make up their minds. If they agree, as I think they will, to some extensive modifications, they have still to fight the matter out with the Local Government Board. Altogether, by the time the four Institutions, the L.C.C. and the Local Government Board have been convinced and have fought out the question among themselves, I fear that many of us will have retired and left behind the cares of active life, but the rising generation at any rate should be enabled to do greater justice to reinforced concrete than is at present possible in the London area."

Mr. A. Alban H. Scott, V.-P.S.A., M.C.I.: "There is such a lot in this Paper that one hardly knows which particular points to take up. First, if I might, I should like to congratulate the author on tackling the subject, and, secondly, I would offer hearty congratulations to Mr. Etchells and also to the L.C.C. for a genuine and splendid set of conditions relating to reinforced concrete. If you just take your minds back to the fact that this is the first set of official regulations in England, that is something of which the Council should be proud. Mr. Twelvetrees has pointed out that the Council had not a free hand. They had practical men, theoretical men, chemists and every imaginable man to deal with as well as the Local Government Board, and, honestly, I think they are to be congratulated on the regulations.

It is somewhat surprising that Mr. Marsh, as a practical man, should seem to forget that the construction of reinforced concrete depends not only on the calculations of the architect or designer, but upon the British navvy. In our own work we reckon to give the most careful consideration possible, because right from the start of my experience of reinforced concrete fifteen years ago we have always recognised that it is about the only material which is used in buildings that cannot be seen and inspected in its actual finished state. If you take constructional steel, even the complicated parts of the work, you can inspect it. You know the nature of the raw material and you can trace it right the way through, and you might say it is of known strength at any part of the work. The same applies to brickwork and to timber (subject to internal defect), but with reinforced concrete you know nothing at all about the strength of the actual structure, and during the period that we discussed the regulations the whole principle I went on was to keep down the excessive loading that some of the other gentlemen wished. Concrete should not be stressed to 600lbs. per square inch;

it is too high. It might not be too high if you properly test the material, but when you look upon the work as it is actually carried out on 90 per cent. of the jobs, it is excessive. When you come to look upon the material as a finished structure and the conditions under which it is put up, I think, apart from the academic interest, it is perfect nonsense to discuss as to whether we are allowed to take 15 or 17.5 for *m*. With regard to testing materials, Mr. Perkins does not see how it is to be carried out, but I would suggest that the L.C.C. should strengthen the regulations in regard to testing materials and that the Concrete Institute's own report on this should be embodied; to a certain extent that has already been done. One problem I can never understand in the American or English regulations, and that is why you should be permitted to deduct a certain loading when you come down to foundations. It does not make a very material difference in the cost of the building, and why it should be allowed is really beyond me, because the only purpose is to save a few hundred pounds at the expense of the safety of the structure. If you are going to allow that, I do not see why you should not allow for additions of a similar nature. I think the foundations and the supporting columns should be equal to the sum of the whole of the units. Mr. Marsh objects to the length of the cantilever being limited to five times the effective depth of the bearing. It would be rather interesting to know if in ordinary building work such a cantilever has been required which would not comply quite easily with that condition. Mr. Marsh gives, I think, approximately one-tenth of the Paper to the question of materials failing under tension, and then suggests he does not want discussion to go away from the L.C.C. Regulations. I cannot accept that in any way. I believe that every material fails, no matter how loaded, in shear and not in tension, but as he does not wish that to be discussed I will not take it any further. Another thing is that in all the experiments we have carried out we found that the strength of the concrete depends largely on the strength of the aggregate as such. A concrete made of granite is very much stronger than a concrete made of ordinary gravel, and the strength of a granite concrete depends on the strength of the granite itself. I do not agree with any of the author's suggestions as to increasing the permissive stress of steel to half the yield point. I think that is inviting disaster. The question of the shrinkage of concrete in the setting is, I think, a subject which requires a good deal

more study. We find generally in a beam about 10ins. wide the actual contraction is about $\frac{1}{8}$in. In regard to anchorage, that is dealt with rather fully, and I do not quite see the object of it, because it would not save very much expense, and naturally the more anchorage you get, within reason, the better the work, especially as the strength of the work depends on the British navvy, and not entirely upon the designer. With regard to columns, I have formed this opinion, that no binding wire in any circumstances should be less than 3in. pitch, and if links are used the links should not be less than 3in. pitch. The steel work of reinforced concrete should not exceed $1\frac{3}{4}$ins. in diameter under any circumstances. There is another point, and that is, that all designs should take some account of fire-resisting qualities. I know the aggregate we are using at the present time is not always an excellent fire-resisting material, but you cannot use coke breeze or clinker for reinforced concrete, and that rather affects the covering to the reinforcement, to bring it more into harmony with the L.C.C. feelings as regards fire resistance. I think all steel should be covered by at least 2ins. of concrete, whether slabs, columns or beams."

Mr. Ewart S. Andrews, B.Sc. (Eng.), M.C.I.: "I congratulate Mr. Marsh on the many excellent points he has made, with the first of which I am in agreement. I have spent some time in criticising these regulations, and I certainly think that in most of the respects, which Mr. Marsh has raised, amendment is not only desirable but really quite necessary. The whole difficulty with regulations of this kind is that the more stringent they are made the more detailed they are made, and the more necessary it becomes, if economic design is to be encouraged, that they shall not become too restrictive. Of course from the official point of view, in order to prevent unsafe construction, there is the tendency always to err on the safe side, and by always giving the benefit of the doubt to the safe side you can easily get to a condition of affairs in which real economy is in danger of being sacrificed and in which originality in treatment and design tends to be put at a discount. It seems to me that one way of getting out of this difficulty, one way which would encourage development, would be to give the option either of complying with these regulations or else to submit the structure, before the building is passed, to a test load which would ensure a satisfactory factor of safety. Such a procedure would re-

quire some consideration before it was adopted in detail, but I would like to see it adopted because it would give ample opportunity for the necessary development in design. There are a large number of problems arising in constructional work in which it is very difficult indeed to calculate the stresses with accuracy. The conditions of the particular building do not exactly fall in with the standard method provided for in the text-books, and it therefore often follows that in conforming with the regulations a considerable increase in strength has to be provided for, and this increase in strength would, on a test, prove to be greater than necessary. That is the principal point that I want to try and make, because I am very anxious that by standardising these regulations we should not hamper development. I am quite convinced that in many of the respects in which Mr. Marsh has criticised the regulations, they *do* hamper development, and while I think that the regulations themselves could and should be modified, the alternative treatment which I suggest would, I think, meet the case in a good many instances which arise. There are one or two points I have noted in a cursory examination of the Paper. I note on page 12 a point which Mr. Marsh has raised before, that of the diagonal tension load. By restricting the stresses to three-quarters the tensile stress, as suggested on page 12, you really come down to the method which I think has now been agreed upon as wrong, of regarding the diagonal reinforcement as in shear. I do not know if Mr. Marsh has any experimental proof of the necessity for the reduction of these stresses to 12,000lbs. per square inch. I have not come across any myself, and I think it really is not quite necessary. I heartily agree that the requirements for high tensile steel should be included in the reinforced concrete regulations. It has been a moot point for many years, but I think the experience which has been obtained in the only steels which have been available for a very large number of people for the last few years has shewn that many of the high tensile steels are quite suitable for reinforced concrete work, and it seems ludicrous not only to prevent their being used to full economy by increasing the permissible stress but actually to prohibit their use at all. High tensile steels are roughly of two classes. There is what is called the artificially worked steel, the steel which depends upon its higher strength entirely on the mechanical working, which higher strength, of course, would be lost with a certain heat treatment. There are also high tensile

steels in which the tensile strength is due to the intrinsic qualities resulting from the chemical composition, and such steels even when annealed provide a much greater strength which would justify a considerably increased working stress. If, as is common practice, all the bars are hooked at the end, you have an automatic test as to the ductility in every bar that you use, because if the steel is unsuitable from the point of view of brittleness for reinforced concrete work, you cannot bend it cold to form a hook without splitting it, and so it seems to me that if you can bend such a bar cold it is prima facie evidence that there is no reason to fear that it will be brittle in its action, and it is therefore acceptable for the form of reinforcement. Another point of very great importance dealt with at length by Mr. Marsh, and with which I cordially agree, is the question of the richer mixtures of concrete. Of course the regulations are now not in such a bad state as they were at one of the intermediate stages, in which by the manipulation of the working stresses in the concrete and the variable modular ratio you found the safe load on a rich concrete for a given reinforcement was less than it was for a poor mixture. That point has been remedied, but we still find a condition of affairs in which the increase of allowable strength for the concrete is quite out of proportion to the real strength of the richer mixture, and for that I see no justification whatever, except that of a meticulous care on the part of the authorities not to run the slightest risk. Whilst I do not wish to minimise the necessity for ensuring safety, I think the great thing we have to keep in mind is, that efficiency is the first point to consider. At the present moment, of course, we are forced to consider economy of material; I am not sure that we are observing it to the extent that we should, because in addition to there being a shortage of steel, there appears to be a shortage of enterprise. If we realise that everybody's interests will be best served by using our materials in the most economical way, we shall get a great advance; we shall get advance in the scientific development of our subject and ultimately everybody will benefit by the use of materials in their most economical form."

Mr. E. Fiander Etchells, A.M.Inst.C.E., A.M.I.Mech.E., V.-P.C.I.: "As Mr. Andrews said, there may be a great shortage of steel, but there is no shortage of criticism, I can assure you. It has been my privilege to be present at no less than 400 meetings and consultations of various sorts at which these regulations

have been discussed and criticised, and therefore it may be assumed I have heard some of these criticisms before; in fact, many of them I have heard so often that the moment I hear the first words I can put down all that the speaker or writer is about to say. The Council are well aware of the necessity for constant revision of the regulations, and the proof is two-fold. First, in 1909 they decided to go in for regulations for reinforced concrete instead of an Act of Parliament, simply because the regulations were easier to alter from time to time. The second proof is from the Minutes of the Proceedings of the Council of June 24, 1913, where the Building Committee report to the Council to this effect:—

> . . . Any increase in the standard of stability may invoke criticism, but as the use of reinforced concrete in building work is a modern development, it is in our opinion expedient to accept the modification made by the Local Government Board, so that the regulations may speedily come into force, and ensure safety in the employment of this method of construction.
>
> If, during the next few years, experience shews that the regulations may, with advantage, be made less onerous, there should be no difficulty in modifying them accordingly.

You see, therefore, that the Council are prepared to consider amendments, but they have also intimated elsewhere that they will not adopt amendments unless the four technical institutions are agreed among themselves as to what the regulations should be. So far, that unanimity of opinion has not been entirely obtainable. The Council have had to do their best under very grave difficulties, and you know after all that the most serious problem is to get any two of you to agree on any one revision. Let me take an illustration. On page 16 of the Paper and for $4\frac{1}{2}$ pages previously, Mr. Marsh discusses with truth and profundity the modular ratio, and in summing it up he says:—

'It is also contended that since the modulus of elasticity of concrete in compression is, at the best, a doubtful quantity, and as other factors must be taken into account when deciding on the value of m, a constant value of 15 for this coefficient is quite sufficiently accurate for the purposes of calculation, and that the assumption of this constant value is justified, under the circumstances, by the simplification it allows in the necessarily intricate calculations required for the design of reinforced concrete members.'

That is Mr. Marsh's summary. On the other hand, at a stage when the regulation contained m as a constant of 15, there were some almost lurid articles in the Press about the

ridiculousness of having it at 15. It was dubbed 'the rubber stamp method,' and those who were responsible for it were supposed to have heard nothing about the variations and barely knew what reinforced concrete was. That critic is here to-night. I hope that he and Mr. Marsh will compose their differences to start with. In the meantime we can go on using the regulations as they are printed. That is only one out of many. Take another case, on page 20. We have carried out that principle of simplification in the case of the regulation in respect of which it is stated, in Mr. Marsh's exact words, 'It is also not at all clear why the diameter of the distributing bars should be limited to at least one-sixteenth the effective depth, nor why the spacing should not be greater than four times the effective depth.' It is manifest by an examination of the two figures, 1/16th and $\frac{1}{4}$, that some simplification has been at work. The building authorities obtained from contractors putting up buildings what was their actual practice on jobs put out to tender. They discovered what it was and took the nearest round figure. The contractors were working, not on any set rule, but on something they had done before, on the last job, perhaps, and that practice was set down and the figures were rounded off. It came out to 1/15th in that case, and it was made into 1/16th and the other figure was 4 and a small fraction.

With regard to some of the criticisms, I would like you to ask yourselves where is the practical hardship. Have you in practice wanted to design a cantilever having a length exceeding five times its depth, or do you want to design a floor of less than 3ins. thickness? Three inches is the minimum thickness under the regulations and 5ins. is the minimum thickness of a fire-resisting floor for insurance purposes."

Mr. Marsh: "Surely you would not allow a building to to be put up which is not fire-resisting?"

Mr. Etchells: "The answer, strange as it may appear, is 'Yes,' if Mr. Marsh had his way and made no restriction as to the depth of the floor slabs. Mr. Marsh says there is no theoretical justification for this, but 'theoretical' seems to run like a refrain through the Paper. This may or may not be the case, but it all depends on what you call 'theoretical.' In every case it is submitted that there is some practical justification for the regulation. I will say more, and that is that if the four Institutions can shew there

is no practical justification for a definite regulation, that regulation will be amended as quickly as ever the legal machinery can be put into operation. He also refers to decimals in the modular ratio. I hope that no District Surveyor will ever hold a job up because the modular ratio comes out to a decimal. I hope you will, as practical men, work to the nearest round number."

MR. PERKINS: "That is what I strive for."

MR. ETCHELLS: "I am sure the L.C.C. are not likely to take any proceedings against you because you neglect a minor decimal."

MR. MARSH: "Would not the sufficiently round number be 15?"

MR. ETCHELLS: "I cannot over-ride the regulations, but what I am referring to now is that when the regulations give you a figure which requires two or three decimals for its exact expression, I suggest you take the nearest round number to that."

MR. MARSH: "The regulations give you an actual figure which runs into three decimal places. You cannot alter the regulations; you must stick to them. You cannot alter to one place of decimals any more than to four. You have no more power to alter one than the other."

MR. ETCHELLS: "We are not lawyers; we are practical men. I suggest that when the regulation gives the modular ratio to three places of decimals you should take the nearest round number, and I hope that no District Surveyor would raise objections on that score.

With regard to pillar stresses, it is possible that some modification may be made there sooner or later, and the question that you have to decide is whether you are agreed to take the cross area of the pillar or only the area of the core. There are many people who would combine the ideas of Mr. Marsh and Mr. Scott to this extent; firstly, accept Mr. Marsh's idea of taking the whole area, and secondly, Mr. Scott's idea of reducing the stresses. That may not alter the design of an actual building very much, but the method would have this advantage, that in dealing with calculations of combined stresses you would be able to combine them better, since when a beam is acting, the extremest fibre is calculated for tension or compression.

There are many other points that could be discussed, but they had better be discussed at a Committee meeting as

suggested by Sir Henry Tanner, and I suggest that the Science Committee, which is a standing Committee, should take up this question and prepare from time to time notes for submission to the other institutions. We will not go into all of them closely now, but I might in conclusion say that when various individuals have voiced their views, let the institutions decide what is the most practical method of design and I can assure you that the authorities will receive their deliberations with that open mind and receptive intelligence that Mr. Marsh rightly attributes to them. But if you adopt every suggestion of Mr. Marsh as good, there will still be a hurricane of criticism from those who differ from him. Nevertheless, we thank Mr. Marsh for his paper which will undoubtedly have an influence when the regulations come to be amended."

Mr. E. Lawrence Hall, M.C.I.: "As regards the testing of materials, is it not always safer to use a cylinder than a cube, a cylinder with a length, say, of 1½ times its side? A cube really gives a false result under a compression test. I should like to ask the author whether the American and Continental regulations support his contentions for altering the English regulations. He has mentioned this point in some cases, but not in others. I think he probably knows what is being done elsewhere. For instance, on the question of anchorage, and whether these other regulations support his view as to what width of the T-beam flange should be considered with the rib; the shear area in the beam; the regulation for distribution bars; the maximum size of bars in columns—whether in other countries greater than 2ins. is allowed; I believe it is. Then the reduction of floor load in calculating pillars; whether other countries do not allow the greater reduction that he suggests, or what is the effect of their regulations in that way. Also as to the reduced stress allowed in steel in diagonal tension members. Then as to calculating the outer covering of pillars; I would suggest that as in a beam you would count the covering of concrete on the compression side, it would be a fair thing to count the concrete on one side of the pillar, which is equal to taking half the covering. As regards stronger mixes, I really think that considering the difficulty of knowing whether you are getting exactly the concrete you want, you should have a higher factor of safety when you are using the richer mixes. I agree, therefore, with the regulations. As to the shear in beams, American practice, I believe, is to allow that the concrete itself always takes

a part of the shear stress, as much as it is able to, and steel shear members are put in to take the balance, whereas here, if the concrete is unable to take the whole of the shear stresses we neglect the concrete altogether and use steel entirely, which seems to me extravagant."

Mr. H. Kempton Dyson, M.C.I. : " I would like to say a few things. On the whole I agree with Mr. Marsh in the majority of his criticisms, and therefore the quickest way will be not to say where I agree but to point out the things where I perhaps differ, or upon which I would like to make a few observations. I think that point of his about the strength of the concrete depending primarily on the strength of the mortar is extremely interesting, and the point about the failure of compression specimens in a brittle material ought to be useful. The point that the failure is due to tensile stresses is a point that I brought out with a number of formulæ in a paper that I read before the Institute some years ago, and I will return to that in a moment in connection with these values for shear, or what I call pinching shear, given in the regulations. As regards the modular ratio of specimens in compression, I do not agree with Mr. Marsh in desiring a uniform modular ratio. I think that we ought to have a variable modular ratio, which tests justify, and I do not think he is quite consistent in making the American Committee back him up in certain things about the strength of mixtures and to ignore the American Committee, who use a variable modular ratio. He does not say anything about himself being adverse to their judgment. He gets their help on one thing, but he does not shew you that they are against him on another. There is one thing about the modular ratio and that is, that it is increased, according to the regulations, in the case of an increased stress on the concrete. I have always been against that. That is to say, the modular ratio multiplied by r, the increased stress, is kept a constant. I contend that that is quite wrong. I want to point out that in my judgment the strength of a concrete, being a brittle material, depends on the cohesion and the frictional resistance of the granular material and that it does not display any considerable lateral expansion when it undergoes longitudinal deformation. That is to say, Poisson's ratio is difficult to determine and you get very variable results. In fact, you hardly get anything at all. There are some materials where you get no Poisson's ratio."

The President : " I will now call on Mr. Marsh to reply

to the discussion. I am sure I may convey to him your very hearty thanks for the care which he has bestowed on this paper and the criticisms he has given of the regulations. It is quite evident from the discussion that many disagree with him, but that does not diminish our debt to him for having brought forward suggestions for economising construction by modifying the regulations. I would certainly echo the suggestion made by Sir Henry Tanner that a Committee should be appointed to consider not only the whole of the scientific investigation and experiments that have been made on this subject, but also the results of actual experience gained during the few years the regulations have been in force. If such a Committee is formed and is able to introduce modifications of the Rules, a great deal of credit will be due to Mr. Marsh for his endeavours to force this matter to the front."

Mr. Marsh, replying to the discussion, said: "With regard to Mr. Perkins' remarks, some of them were dealt with in the course of the argument, but there was one in which he tried to justify what we might call the theoretical strictures of the regulations by reason of faulty construction. Surely the two things are entirely apart. You should surely regulate for faulty construction by itself and guard against it in that way, instead of providing unduly strict regulations with regard to design generally in order to guard against faultiness in construction.

With regard to Mr. Alban Scott, he dealt with very much the same point as Mr. Perkins, which I have tried to answer, and there again I bring out the point that the regulations are quite fair and reasonable in many respects and that they are restrictive in others, and if the point in making these restrictions was to counteract bad construction, then the same thing applies throughout, and each portion should be equally restrictive. Mr. Scott asked for the reason of the reduction of the loading on columns; in paragraph 1, five per cent. and ten per cent. are mentioned. I do not know whether he meant to ask why it was necessary to reduce at all or whether it was legitimate to reduce at all on lower floors. Of course, I believe the reason for that is, that all the floors cannot be fully loaded and you calculate each floor as if it was fully loaded and allow the reduction by reason of the fact that the loading is not the full loading for which you have calculated.

Two or three members, including Mr. Etchells, were

rather down on me on the point of the length of the cantilever. I was not objecting to whatever it is; what I was saying was, that paragraph 28 should be worded in the same way as paragraph 27. There is no reason why a cantilever should not be dealt with in exactly the same way as a beam, as far as the effective length is concerned. Mr. Scott also said he had never constructed a column with the binding further apart than 3ins. Of course, I have nothing to say against Mr. Scott designing his columns as he likes, and certainly he would ensure the strength of the columns in that way. There is nothing against it, but I would like to bring this out—that thousands and millions of columns have been put up with the bindings very considerably farther apart than that and I think they have stood perfectly well. There is no indication that they are likely to fail, and really I cannot see why the restrictions as to binding should make designers put their bindings nearer together than has been found good practice in the past.

With regard to Mr. Andrews, I do not personally treat the diagonal tensile requirements as resisting shear. I calculate them as resisting tension, but my point was rather this, that with regard to the design of the beam, it is usual to take the shear as your basis of calculation, and that is a very doubtful quality. You cannot calculate it accurately, and therefore it is better to reduce the safe stress. The 12,000 is, I am sorry to say, quite an arbitrary figure; I do not know that it has got any justification.

With regard to the modular ratio, Mr. Etchells suggests using the nearest round number. I cannot see, if that is the case, why we should insert a formula for calculating this thing. Why not give actual numbers for each mixture? Whoever framed these regulations could just as easily have rounded them off himself and put them in. One of the members raised the point as to the Americans. The Americans, it is true, use different figures, but they most of them—in fact, I think all the professors who are dealing with this factor—always take the initial value of the modulus of elasticity for concrete and, of course, the initial value for the modulus of elasticity for concrete is very different from that of the modulus at the safe resisting stress. I think the main point is that the value should be taken at about the resistance you are going to allow."

Mr. Perkins: "At the working stress?"

MR. MARSH: "There or thereabouts, and it makes a considerable difference when the curve is parabolic.

Then Mr. Hall asked whether the American regulations supported me or not. As a general rule they do. I think I can safely say that. In many cases the L.C.C. regulations include regulations which are not in the French, American or German regulations. There are a great number of local ones in America which are all more or less arrived at in the same way; but with regard to the floor load—I am speaking without the book—I do not believe the Americans deal with that at all."

MR. ETCHELLS: "It is part of the New York Building Code which was adopted by the R.I.B.A., and is in the General Powers Act for steel frame buildings, and it is repeated in the reinforced concrete regulations. It is in most American codes."

MR. MARSH: "That is a steel frame code."

MR. ETCHELLS: "It is in most American codes for any class of building."

MR. MARSH: "With regard to Mr. Hall's point, I have no objection—I do not think anybody has—to the allowance for 1 : 2 : 4 concrete. If the latter is right, then the richer mixtures should have higher stresses, and if you are not going to allow higher stresses on the stronger mixtures because they are going to be badly made, you ought to reduce it equally on the 1 : 2 : 4. There is no reason for treating the richer mixtures in a different way to 1 : 2 : 4, which is the weakest."

MR. HALL: "But the foreman begrudges that extra bit of cement and he will begrudge it just as much in the 1 : 2 : 4. He can understand ordinary proportions, but when it comes to putting in different proportions he begrudges it."

The discussion then closed.

MR. MARSH subsequently submitted in writing the following additional remarks: "In order to answer in detail the whole of Mr. Hall's queries it would be necessary to quote large extracts from the Final Report of the American Committee on Reinforced Concrete, as their methods are in many cases not the same as have been adopted in preparing the L.C.C. Regulations, and it is therefore difficult to make comparison without lengthy explanation.

I do not think there is any special reference in the

American Report to the reduction of floor loading in calculating for pillars. The American Report allows the whole area of the concrete to be taken into consideration in the case of a column reinforced in the ordinary way.

With regard to the shearing stress in beams, when it is found requisite to use diagonal tension reinforcement it appears to be hardly necessary to consider the concrete. There is very little advantage in allowing for the shearing resistance of the concrete, as it is generally found that it is necessary to insert a quantity of steel which affords ample resistance without taking the concrete into account. The resistance of the concrete should, of course, be allowed to take the whole diagonal tension stresses in such portions of the beam where it is found to be sufficient without the necessity of reinforcement."

SEVENTY-NINTH ORDINARY GENERAL MEETING,

THURSDAY, MARCH 21, 1918.

THE SEVENTY-NINTH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held on Thursday, March 21st, 1918, the President, Mr. F. E. WENTWORTH-SHEILDS, in the Chair.

The following gentlemen were submitted for election and were duly elected by the votes of the Meeting :—

MEMBERS.

MR. ALFRED HAROLD EDWARDS, M.J.I.E., London Manager to Messrs. Redpath, Brown and Co., Structural Engineers.

MR. JOHN GOODHART EVANS, M.J.I.E., Manchester Manager to Messrs. Redpath, Brown and Co., Structural Engineers.

MR. CHARLES CORBETT POWELL WILSON, of Victoria, Australia (re-elected).

THE PRESIDENT called upon Mr. H. L. Barraclough, M.C.I., to read the following paper :—

THE CONCRETE INSTITUTE :
AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, Etc.

Date of Reading: March 21st, 1918.

Some practical points in the design and construction of Partitions.

By H. L. BARRACLOUGH.

Having been asked to write something on the use of partitions, I had almost thought their common use and infinite variety would scarcely have required anyone to ask further information on the question, a matter of some difficulty owing to the simplicity of construction.

Like many other things, the war has brought partitions into an almost endless number of uses, one of which has been for the building of huts and houses. Though this may be new to some, the writer has been concerned in the building of schools and sanitoria, some years ago, with plaster slabs, cement rendered outside, and those places stand to-day as good as when erected.

When partition slabs were first used they had to meet some stern opposition from those always present in a community who oppose anything new. Even to-day one meets with people who are opposed to innovations. However, we may thank the evils of war for dispelling some objections concerning partitions.

Simple as it may seem, the erection of partition slabs, as experience has proved, should only be entrusted to the hands of men used to this particular class of work. A badly built-up job is sure to develop cracks in unthought-of places, the blame very often being fixed on the manufacturer of the particular partition slabs. This long-suffering individual very often has little means of replying to the criticisms, where the slabs alone are supplied by him.

There are several kinds of partition slabs manufactured

and on the markets :—Breeze, pumice, plaster and clay, each of which has its special claims.

Plaster, until recently, has been the most common in use, and has many advantages over breeze slabs. Solid plaster slabs are light, easily fixed, with little or no waste in erection. When up, they form a solid wall, hygienic in all ways, as every possible lodgment for dirt and vermin is effectually closed after the walls have been plastered out, and are fire and sound-resisting, provided the work has been executed by skilled labour, which goes largely to ease the question of after-cracks.

My opinion is, that hollow plaster slabs, although lighter, have some objectionable features, the compressional strength of the slab having been somewhat destroyed through the apertures; and further, if spiking is resorted to for fixing, very often the spikes crack the slabs when being driven in, and generally weaken the whole wall.

In fixing plaster partition slabs, it is essential that the suction should be destroyed by applying a thin cement wash, and that they should be well bedded in plaster in preference to spiking.

It is preferable that all slabs, used for partition work, should be tongued and grooved horizontally and vertically, and in fixing, the grooves should be placed upwards and the joints broken, as in brickwork, and the vertical joints carefully grouted in with plaster, both where they join up to the door frames or brick walls, and where they butt against each other. Where a slab has to be cut it is advisable to form a groove by scooping a piece out.

Plaster slabs have been successfully used for external works fixed on wood framings and faced with tiles, but this is an expensive form of work, and if not carried out by experienced labour, the tiles are liable to come off.

Seven years ago, two inch plaster slabs were used for internal and external walls of a school in Northumberland. The slabs were fixed to wood framing on outside, rendered over surface with cement mortar, floated to an even surface and rough cast with a mixture of slag and pea gravel, one inch internal slabs nailed to framing floated and skimmed with washed haired lime and putty, and finished with putty and plaster throughout, a dado of 3ft. 6in. being formed with Portland cement back, and finished with Keene's cement face trowelled smooth. It has proved a very satisfactory construction as well as cheap.

A well-known firm has recently introduced a plaster slab

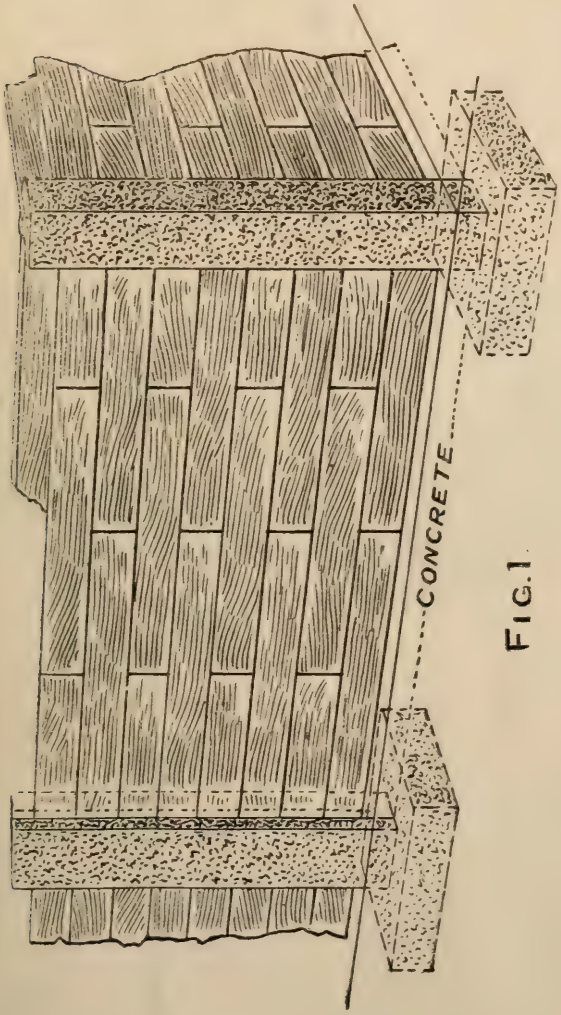

FIG. 1.

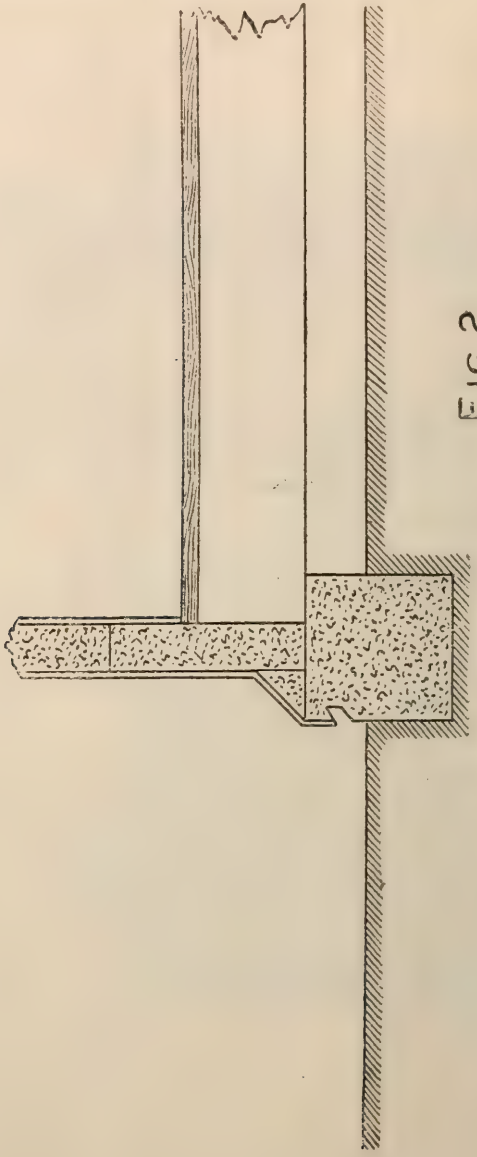

FIG 2

with a special face to receive cement rendering for external work, and they claim that it will withstand the weather for twenty years without being re-rendered. These have been used for external works on several jobs in the Midlands, and would appear to be eminently suitable for a cheap-system cottage or bungalow building. This system could be used in conjunction with light reinforced concrete piers and beams (as Fig. 1) or wood framing, and has the advantage of being a very rapid construction. Doors and windows can practically be fixed in any position, as the openings can easily be cut, after the wall is up, without much danger of damaging other parts.

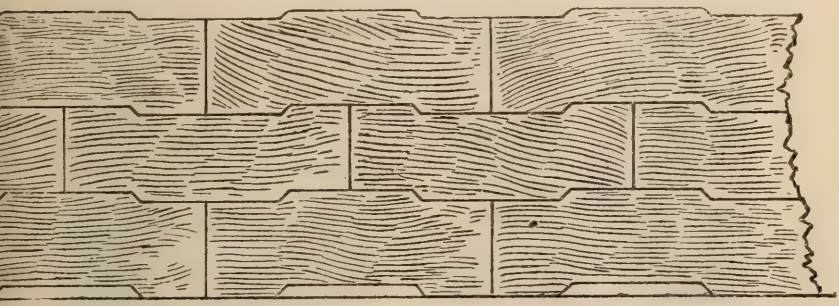

FIG. 3.

The foundation need only be 9in. depth of good concrete under the wall, weathered on the outside, doing away with the necessity of any damp course (Figure 2).

Breeze partition slabs are manufactured by several firms, in various sizes and shapes. They are light, and one on the market, to my knowledge, affords a first class key for fixing, and is cast with an indentation with horizontal edges (as Fig. 3). There is always a danger that the breeze used in manufacturing slabs may contain sulphur, which will in time discolour the plaster and cause it to scale off; and where the partition is faced with tiles, the latter will crack and often fall off, from the action of the sulphur which seems to go on for a long time, thus causing much annoyance and anxiety, and where used it is advisable that the slabs should be obtained only from a firm of sound repute.

The pumice slab is a very light form of construction,

convenient to handle, and is manufactured from pumice and volcanic sand (imported into this country from Italy) mixed with Portland cement. These slabs form a rigid construction when up. Nails can readily be driven into them and take a good hold, doing away with the necessity of plugging for fixing skirtings or picture rails.

The hollow terra-cotta partition tile is well known to many, and can be obtained in different sizes from several firms, and has the advantage of being easily handled. It can be obtained with a keyed or smooth face, and is being used just now extensively for exterior work. It is easily built up, the horizontal joints being bedded with cement, and the vertical joints grouted up, and seems to be quite effective in withstanding the weather, but it has only come into prominent use for this purpose recently, owing to the present shortage of other materials, and it remains to be proved what effect time will have on it. I am, however, strongly of the opinion that there are several points in its favour for this purpose, being cheaper than a brick wall of the same thickness, resists the damp better and ensures a more even temperature, but does not lend itself to nailing. Where it is necessary to fix skirtings and rails, provision should be made for same at the time of erection by carefully inserting plugs in the joints. Should this not be done at the time of erection, and it is found necessary to fix electric fittings or hook rails, the joints should be cut out, and a plug built in, as any attempt to drive a nail into the tile is generally a failure, besides being liable to break the face of the whole tile.

Those of us who have had to do with partitions know only too well that they mostly have the annoying habit of showing cracks which more often than not go right through. These cracks may develop from either of the following causes :—

The cracks generally occur just under the ceiling or near walls and door frames, or at top corners of door frames. The cracks at the tops or by the walls may be caused by variation of temperature, causing expansion or contraction, or through the supports deflecting or settling. Cracks also are generally to be found on top storeys of buildings with large flat roofs, owing to the expansion of the flat as well as the partition, and up to the present I have not seen any successful method of stopping this occurring with a built-up partition, for even when cut and carefully filled in, the cracks will readily appear again.

The cracks on doors are particularly noticeable when the jambs project a few inches above the frame, and this is caused by the wood frame swelling, through absorbing the moisture from the partition whilst it is being erected. These can generally be stopped up successfully if cut out and filled in, after the partition has had time to dry out, and will not appear again, provided the door frames are fixed rigidly enough to prevent the partition from being shaken when the door is shut quickly. The best remedy, however, is to prevent this by stopping the door jambs off flush and carrying the partition over in one slab (as sketch No. 4).

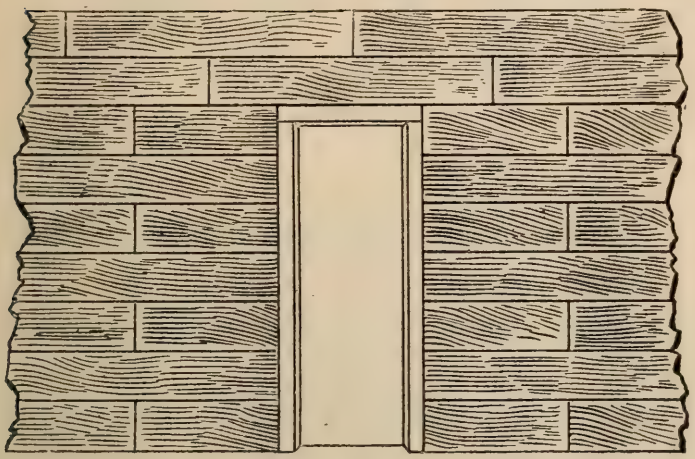

FIG. 4.

This method is now recognised by most practical fixers as the best, and with few exceptions, is carried out wherever possible.

The position of a partition is too often left to be settled after the floor and beams are all in, and then it is placed anywhere, whether the weight is supported by a main beam or only by the floor, and more often than not gets placed on the floor, away from the main beam, which may only be calculated to carry a load of 100 lbs. per foot super; whereas many 3in. partitions, when plastered both sides, weigh 18lbs. per foot super, and 10ft. is quite an ordinary height for such a partition, therefore, one foot run would

weigh 180 lbs. The heaviest articles of furniture in domestic buildings are generally placed against the partition, and in an office it is quite an ordinary occurrence to find a heavy safe one side and a tier of shelves filled with books and papers on the other. Taking the total weight of the safe at 15 cwts., placed in the centre of the bearing, and the bookcase at 2 cwts. per foot run, we find, if a 3in. partition, 12in. wide × 10ft. high, happens to be placed on the floor as per diagram, we get the following load per foot super in that particular place:—

3in. partition—18 lbs. per ft. sup. × 12ft. wide × 10ft. high = a distributed load of	2,160 lbs.
1 safe = a distributed load of 30 cwt. =	3,360 lbs.
1 tier of shelves 10ft. wide at 2 cwt. per ft. run = 20 cwt. = ...	2,240 lbs.
Giving a total load of	7,760 lbs.

Taking the width of floor occupied as 3ft. × 12ft. = 36ft. sup.

Therefore, 7,760 lbs. ÷ 36 = 215.5 lbs. per ft. sup. on this particular portion of the floor, which is more than double what the floor weight and main beams were calculated to carry, and except for the large safety factor required by the authorities, there would be more than mere cracks appearing. The writer is strongly of the opinion that the position of all partitions wherever possible should be settled at the time of planning, and proper beams arranged to carry them, and when this cannot be done, it is advisable wherever possible to have partitions cast in situ and reinforced with small steel rods, forming a beam from wall to wall. This method has been carried out by me and has always proved most satisfactory, and helps very considerably to tie the wall and distribute its load more evenly, and costs very little more than a built-up partition; being quite solid in construction, it is thoroughly hygienic (see sketch 5).

There is yet another means by which a partition can be constructed without slabs, and where a very thin partition is required, it has many advantages, as when finished and the whole thoroughly set, it forms a very strong and rigid structure, being light, occupying little space, and being

practically sound, fire and vermin-resisting. There is no temporary sheeting or strutting required, and the work can be done with little labour.

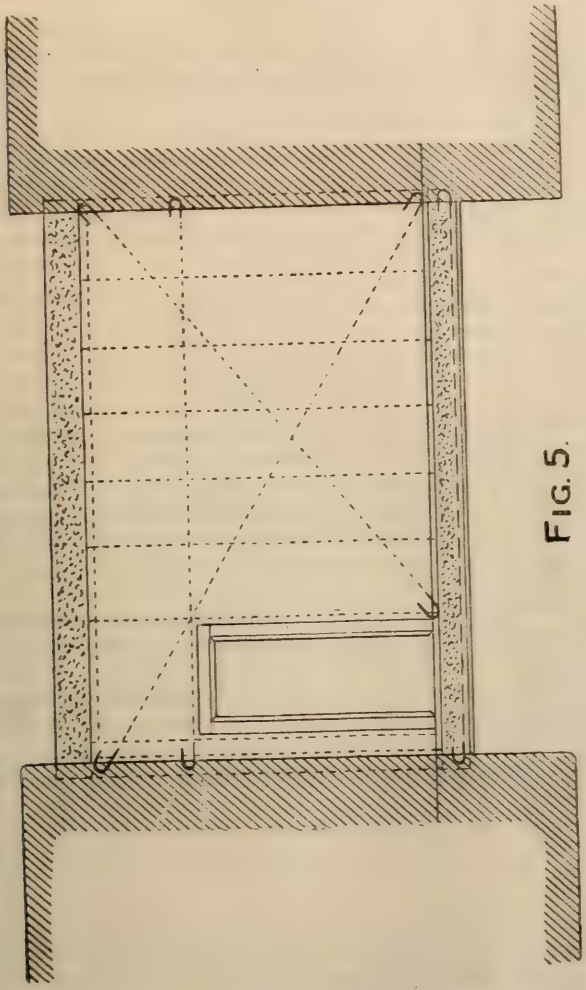

FIG. 5.

The foundation work usually consists of vertical rods, securely and tautly fastened at top and bottom by screws, nails, or clamps at about 12in. centres. To these supports

expanded metal lathing is firmly secured by soft wire or some other convenient means, and both sides covered by any quick and hard-setting plasters, which can be finished to a smooth face without loss of time.

The solid partitions are sometimes built only 1½in. thick, but generally made to finish 2in. thick, and can be used in combination with any class of concrete floors and ceilings, or ordinary wooden floors. Doors and other openings that may be required for lifts or ventilation can easily be formed and frames securely fixed in position at the time of construction, or after the partition is up. The whole forms a partition possessing all the desired advantages of a divisional wall not required to carry any weight, and occupies the least possible space for such purposes. This class of partition is very suitable for internal lift wells, where good anchorage can be obtained for the vertical tie rods, as it takes up little room and stands vibration.

CONCLUSION.

These are only a few of the many classes of fire-resisting partitions, but I have endeavoured to include those most generally used. I have avoided mentioning the names of any particular manufacturers, as many are known to all of you, and I trust that you have not been bored by my effort to explain a few practical details in connection with my experience of the past.

As mentioned previously, one of the most troublesome things in connection with partitions is their habit of cracking.

I hope, however, that some useful information regarding a cure for the complaint, may be brought out in discussion, as no doubt partitions will play an even larger part in future constructions of small property than it has done in the past.

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DISCUSSION.

THE PRESIDENT said the subject was an extremely important one. He agreed with the author that partitions would play an extremely important part in future construction. In the past, timber had been so easily obtained that little else was used for them. But the war had given prominence to the use of timber substitutes, and there was no doubt that after the war, home-made products such as those mentioned in the paper would be very largely used for partitions.

Mr. E. FIANDER ETCHELLS, A. M. Inst. C. E., A.M.I.Mech.E., V.-P.C.I., also agreed that partition work would play an important part in the future. Under the earliest London Building Acts, walls of 3ft. thickness were specified, but under later Acts the thickness was reduced to 13½in., 9in. and 4in. This gradual reduction had been accompanied by a change in construction. There had been a development towards frame construction with a diaphragm stretched across the framework. The war had been an incentive to economy, and hundreds of buildings had been approved which would not have been passed before the war, the walls of which were mostly 3in. partitions with ¾in. rendering on the outside and ¼in. on the inside. In the earliest examples of this form of construction the slabs were bonded into the brick piers by cutting away some of the pier or some of the slab, so that there were only some teeth sticking into the pier. But now the procedure seemed to be to have a groove in the brick pillar 18ins. high, 4½ins. deep and 3ins. wide so that every alternate slab fitted into that recess. That saved a lot of cutting of the brickwork and of the slab, and afforded a good bond for the slab itself and also helped to support the brick pillar, in one plane at any rate.

With regard to the cracks in internal partitions, one of the reasons was that the weight of the internal partition was very often not allowed for, and until definite rules were established with regard to that, there were bound to be cracks. Some of them were serious. They ran along the top and frequently diagonally down to the corners of

the room. In one case which came under his notice, the floor of the building supported a heavy safe, but there was no beam underneath where the safe stood. The result was that the deflection of the floor caused cracks to appear in the neighbouring partitions. In many cases designers seemed to think that the laws of wind pressure did not apply to slabs. In other cases the slab walls, which were too high, bulged under their own weight. When dealing with slab partitions it was necessary to keep an eye on the designer to see what assumptions he was making for his weights and pressures.

Mr. W. J. H. Leverton, M.C.I., referred to a statement at one of the R.I.B.A. conferences that porous terra-cotta slabs were made of sawdust mixed with clay and that they could be sawn and nailed quite easily.

Mr. A. Stewart Buckle, M.C.I., M.S.E., said there seemed to be some uncertainty as to the distance apart that the piers should be for slab construction.

Mr. G. McLean Gibson, M.C.I., suggested that it would be necessary when using plaster slabs for outside construction to have a covering over whilst they were being put in, as a protection against rain. The size of the slabs shewn in the author's photographs seemed to him abnormal. If they were only 3ins. thick and 1ft. high they would appear to be 5ft. or 6ft. long and would require great care in handling. Most slabs were made of a size that could easily be handled by one man, whereas these seemed a good load for two men. He was more interested in using these partitions as makeshifts for outside work, and in that connection he found the plastering an expensive matter. In one building with which he was concerned, grip partition blocks were used with diagonal wiring on both sides, rendered with cement. They made a very strong job, and the makers claimed that they were as strong as a 14in. brick wall. The thickness of the block was 2ins., and with the rendering on both sides the total thickness was 3ins., and at the prices of a year ago it cost about 8s. 6d. a yard to fix. The price of the block was negligible, about 1s. 6½d. per yard. He advocated partition blocks for outside work where no rendering was required, and for this a 2in. terra-cotta hollow block 12ins. by 12ins. was found to be very good. Another type of block which had been used to a large extent was

the sand-lime and the sand-cement block, about 2½ins. thick and 18ins. by 9ins., which was just big enough for a man to handle alone. When fitted in with Portland cement and properly bonded they made a good clean wall inside and outside. With these blocks a wall could be finished for about 5s. 6d. per yard. The piers to take these blocks were very often built at 8ft. centres, special blocks 9ins. by 9ins. by 6ins. with a 2½ins. groove being used. He would not go more than 9ft. high with such slabs. Many of these partition walls looked well when first put up, but it was another tale after a year or two. He had already found trouble with sand-lime blocks through the free lime in them.

The President asked if these sand-lime blocks were simply hydraulic lime and sand.

Mr. Gibson said he did not know how they were made. They were a proprietary article.

Mr. Etchells warned members to be extremely careful with regard to advertisements which claimed that a 3in. plaster partition or a 3in. slab partition was as strong as a 14in. wall. They must bear in mind two facts; first, that the cement mortar was the same in the slab as in the brick wall; and that it did not alter its strength because it was in a slab. Then it should be remembered that the strength of walls acting as vertical beams was proportional to the square or second power of the depth. In the case of the 3in. slab, the second power would be 9, and in the case of the 13½in. wall it was about 180, so that the strengths were in the ratio of 20 to 1 in favour of the 13½in. wall. At the same time, it was the fact that the slabs got a certain amount of strength when faced with cement and also that they were often supported on four edges, whereas a brick wall might only be supported at its base.

Mr. Gibson said that the reason why a partition was used instead of a brick wall in the case he had mentioned was that it was a steel frame building of four storeys and the enclosures were commenced from the fourth storey and carried downwards.

Mr. Leverton suggested that a partition was much stronger than a brick wall because of the fewer joints.

Mr. Buckle said the latest development in this type of

construction was to be seen in St. James's Park at Storey's Gate, and although the building was apparently intended to be a temporary one, it was really a permanent one. This building, opposite the Institution of Mechanical Engineers, appeared to be the latest development of the Office of Works, and it consisted of brick piers and slabs. They were cutting out grooves in the piers, which was what Mr. Etchells said should not be done. He himself had a design in hand and was going to build with a groove the whole way up the piers, but was glad to hear that it was not necessary. It would be interesting to know what was the best sort of slab to use both for inside and outside.

The President, in proposing a vote of thanks to the author, asked how the plaster partition was really made. Was it simply plaster and water, or was there something else in it which made it stronger and more durable than plaster of Paris alone? As to preventing slabs settling, it might be possible to do this by reinforcing with a light wire or with steel rods. He should like to know whether any attempt had been made to mix Portland cement with some other material that would allow nails to be driven into it. Slabs of such a material would be most useful.

Mr. Barraclough, in reply to the discussion, said he believed there was a terra-cotta block on the market for which it was claimed that it could be nailed without cracking, but he had had no experience of it. In the case of outside plaster partitions mentioned in the paper, tarpaulins were ready at hand in case it rained. Even in storage in damp places, these partitions often became quite sodden and were liable to break when being picked up. He did not advocate more than 13ft. centres for piers. Some travellers had advocated 18ft. and even 25ft. and 30ft., but although he had been promised photographs of such constructions, they had never come to hand. He had been very unlucky in connection with breeze slabs, although he had not been responsible for putting them in. He had had pieces cut out of walls so constructed, and found all sorts of things inside, including rusty iron, free sulphur and lime all mixed together. If there was only one bad slab of this nature among dozens it seemed to have a very bad effect upon the whole structure. In one house in the West End, which had been up for three years, the contractors had had to put the wall in the bath room right no fewer than four times. The foreign matter

in one of the slabs seemed to have affected the whole of the tiles. If the slabs were made of clean breeze, however, there should be no trouble.

The meeting then terminated.

EIGHTIETH ORDINARY GENERAL MEETING,

THURSDAY, APRIL 25, 1918.

THE EIGHTIETH ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE was held on Thursday, April 25, 1918, Mr. CHARLES F. MARSH, M.Inst.C.E., Vice-President, in the Chair.

The following gentlemen were submitted for election and were duly elected by the votes of the Meeting :—

MEMBER.

MR. THOMAS CAMERON HALLIDAY, M. S. Africa Soc. C.E., Town Engineer, Queenstown, Cape Colony.

ASSOCIATE MEMBERS.

MR. PERCY ARMITAGE ASTLEY, Structural Engineer and Architect, Huddersfield.

MR. JOHN ARCHIBALD BROWN, Building Surveyor, London.

MR. ALFRED DUCKWORTH, Architect, Fleetwood.

MR. MASAHARU UTSUMI, Graduate of Japanese Imperial University, Civil Engineer to the Osaka Military Arsenal, Japan.

THE CHAIRMAN then called upon Mr. H. J. Deane, B.E. (Sydney), M.Inst.C.E., M.Inst.M.E., M.C.I., to read the following paper :—

THE CONCRETE INSTITUTE :
AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, ETC.

Date of Reading: April 25, 1918.

The Charterhouse Street Cold Stores of the Port of London Authority.

By H. J. DEANE, B.E. (Sydney), M.Inst.C.E., M.Inst.M.E.

INTRODUCTORY AND HISTORICAL.

The scope of this paper does not permit the inclusion of a review of the growth of business in frozen or chilled produce as facilities in carriage and cold storage developed, nor yet an exposition of the advantages of cold storage in enabling perishable produce to be transported from great distances and through tropical temperatures, whilst at the same time preserving it in a condition for distribution to and consumption by the public. But a few brief words on the subject of cold storage in the Port during the early days may not be amiss as introductory to the principal subject of the paper.

Definite progress in refrigeration and cold storage can be said to date from the commercial introduction of mechanical means of producing cold between 1870 and 1880. Since then many improvements have been made not only in the efficiency of the machinery and methods of insulation, but also in the process of cooling and freezing and handling of the produce to be preserved.

Towards the end of 1880, and following on the first successful consignment from Australia of about 40 tons of sheep by the s.s. "Strathleven," further experimental shipments of Australian meat were being expected, and, in anticipation, the London and St. Katharine Docks Company, proprietors of the Royal Victoria and Albert Docks, undertook in the following year the equipment of a certain section of the vaults of "A" Jetty (now known as "B" Jetty) Victoria Dock with a small cold chamber and cold air refrigerating engine by Messrs. Hall, of Dartford.

The Orient Company's s.s. "Cuzco," which had been equipped for the purpose, duly arrived in the Victoria Docks on September 6th, 1881, with what must be considered as the pioneer shipment of 160 tons of meat "preserved by the new refrigerating process." The consignment, which consisted of 4,000 sheep and 100 beef carcases, was discharged about a week afterwards and stored in the new cold chamber just referred to. This experimental shipment was so successful that (to use the words of the old records) "it has been determined that all the Orient Company's boats shall forthwith be fitted with refrigerating chambers." Another vessel, the s.s. "Protos," also appears to have arrived about the same time, or a little earlier, with about 600 carcases of sheep on board which, when placed on the market, realised from 6d. to 6½d. per pound.

In July, 1882, the East and West India Dock Company equipped a small hulk called the "Seawitch" with an insulated chamber and refrigerating machinery by Haslam, and this was followed at a later date by another hulk, the "Robert Morrison." They were easily transported from dock to dock, the advantage claimed for this arrangement being that the store could be taken to the vessel for loading and unloading wherever she might be. Developments at the Victoria and Albert Docks followed after the equipment of the "A" Jetty vault, and in 1887 a new Cold Store was built and the old vault chambers (which had been further extended) put out of commission. The latest addition, prior to the inception of the Port of London Authority, was that known as "No. 5 Block," which was completed in 1902. In the meantime the inconvenience of the long journey from the Docks to the market had been felt, and, in order to provide against delays in transit and the minor fluctuations in demand at the Central Markets, the Dock Company constructed a Cold Store at St. John Street, West Smithfield.

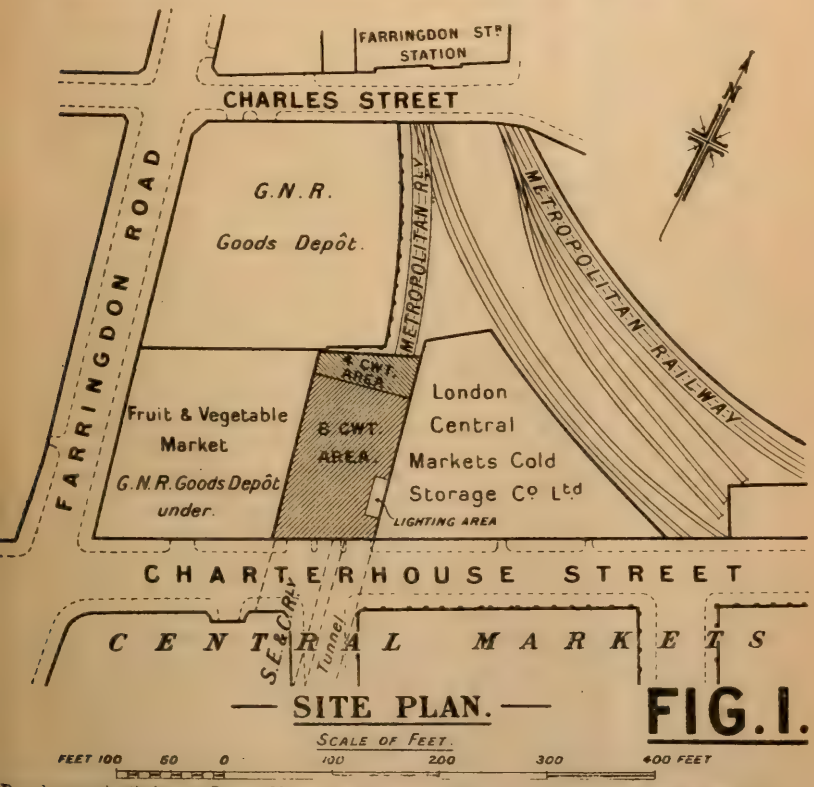
The total accommodation at the time the undertakings of the Dock Companies were transferred to the Port Authority was over 2,000,000 cub. ft. (exclusive of the Surrey and West India Docks Stores), the West Smithfield Stores accounting for 365,717 cub. ft. of this quantity.

(As a matter of general interest and indicative of the development of this section of the undertaking, it might here be mentioned that a large Cold Store is at present being erected at the Royal Albert Docks, where the latest appliances for the rapid handling and storage of meat are

being installed and accommodation for half a million carcases is being provided, the total cubic contents being about 2,620,000 cub. ft. of refrigerated space.)

Soon after the Port Authority came into being it became apparent that the West Smithfield Store was inadequate for the requirements of the trade and that further facilities in the way of cold storage were an urgent necessity.

The absence of a more suitable site ultimately led to negotiations being concluded with the City Corporation for the lease of an area of about 17,100 super ft. on the north side of Charterhouse Street, immediately opposite the Central Markets and situated over the railway connecting Farringdon Street and Snow Hill Stations (Fig. 1).



— SITE PLAN. —

FIG. 1.

SCALE OF FEET.

Based upon the Ordnance Survey Map with the sanction of the Controller of H.M. Stationery Office.

THE CARTON PRESS, LTD.

The site, from an engineering point of view, is probably one of the least desirable that could be conceived. It consists of a raft or platform constructed of built-up steel girders (varying from 39¼ins. by 18ins. to 40¾ins. by 24ins. and spaced 8ft. apart), with brick jack arches and concrete filling between. With the exception of those on the eastern side, which are carried directly on to stanchions, the cross-girders are supported on three rows of main girders of varying dimensions which are in turn supported by steel stanchions encased in concrete. The spacing of the main stanchions is governed by the position of the permanent way of the three railway companies over which the platform has been constructed, as well as by other local conditions.

Each of these railway companies has a lively interest in any operations which take place over its lines, such interest being safeguarded by agreements with the Authority's landlords of a comprehensive and far-reaching character. The provisions of all these agreements are fully protected in the Authority's lease with the Corporation.

The allowable loading of the platform is necessarily limited to that for which it was designed, and the terms of the lease prohibit the imposition of any greater loading than the 8 cwts. and 4 cwts. per ft. super over the areas shown in Fig. 1. These limitations were responsible for a good many of the most interesting features in the design of the building which now stands upon that area. Another proviso in the lease which affected the design was the preservation of certain rights of light and air enjoyed by the London Central Markets Cold Storage Company immediately to the east of the site, and the area which had to be left free for this purpose will be seen on reference to Fig. 2. Had it been possible to utilise this space for cold chambers a further 18,000 cub. ft. might have been added to the accommodation. The Great Northern Railway Company also claimed rights of light and air in respect of its premises on the north side of the site, but although the validity of the claim was open to question, it was found possible to modify the design of the building to meet the wishes of the Company without involving any sacrifice in the accommodation.

Fig. 5 shows a section through the cross-girders of the platform, and the lines of the main girders are shown in Fig. 2 by the letters A.C., D.K., L.R. On reference to these drawings, it will be obvious that all concentrated loads had to be arranged either to come directly on to the girders or be transmitted thereto by means of distributing girders

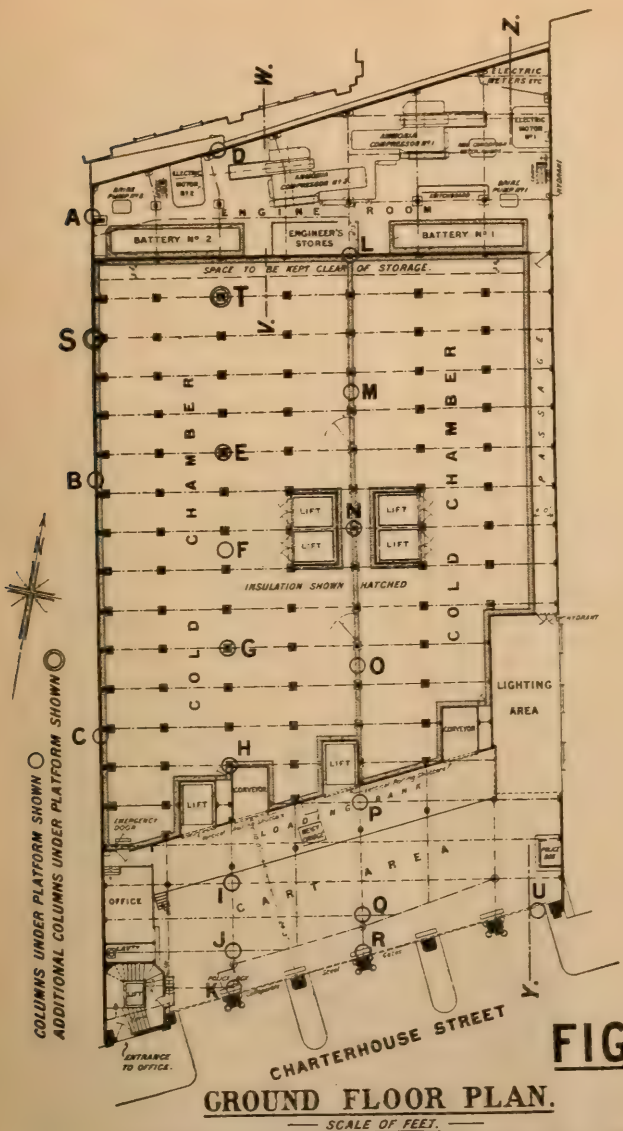


FIG.2.

GROUND FLOOR PLAN.

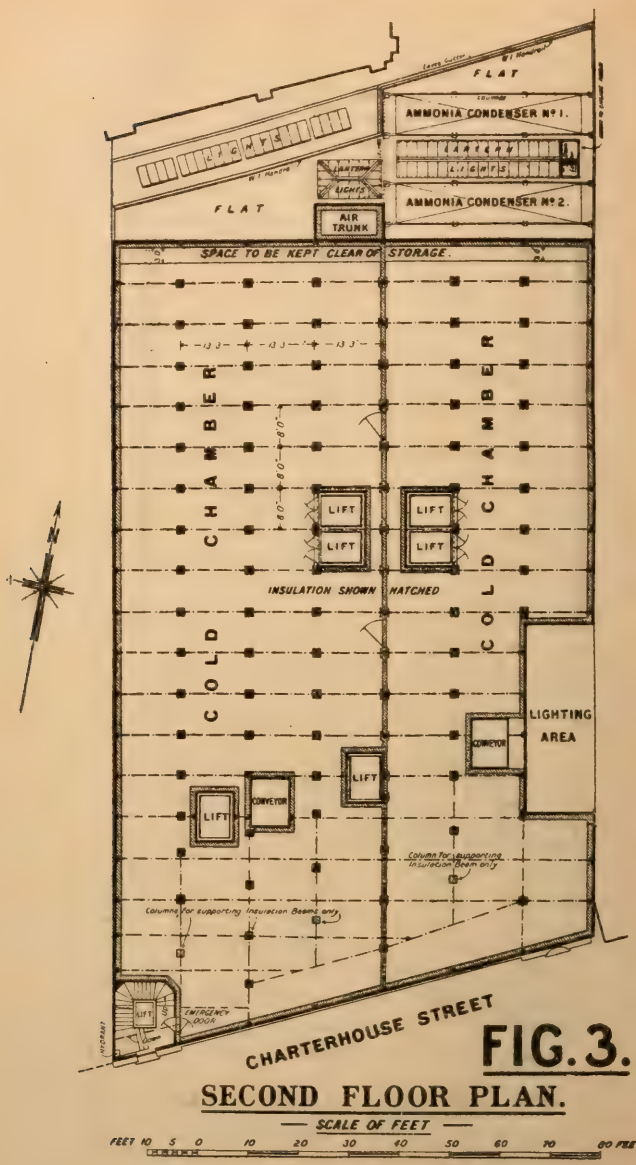


FIG. 3.

SECOND FLOOR PLAN.

SCALE OF FEET

or grids, and this is responsible for what would otherwise appear to be an unusual arrangement of the columns. Under such conditions the designing of a building, which not only had to satisfy these limitations, but had also to provide facilities for loading and unloading, sorting to marks, office accommodation, handling appliances, engine-room space, combined with the largest capacity possible for the storage of produce, was a matter which required very careful consideration and a great deal of calculation before the final arrangement could be arrived at.

GENERAL DESCRIPTION OF THE COLD STORE.

The building generally is constructed of reinforced concrete, faced on the Charterhouse Street side with granite and Portland stone. It has three floors, in addition to the ground floor, the cold storage chambers being situated on the ground, first and second floors (Fig. 3 is typical of the two latter floors), whilst the top floor (Fig. 4) is utilised for sorting and distributing of produce and for office accommodation.

The refrigerating machinery is placed at the back of the building on the ground floor level and occupies that area of the site which is limited to a loading of 4 cwts. per sq. ft. Access to the Machinery Room is given by means of a passage along the east side of the building, in which accommodation is also found for the storage of the ammonia bottles. The roof flat over the Machinery Room is of reinforced concrete construction, and access thereto is afforded by an iron staircase through a hatchway leading to the Ammonia Condensers, etc. (see Fig. 5).

On the Charterhouse Street side is provided, under cover of the first floor, a cart area and loading bank (see Fig. 2), from whence communication between this and the top or sorting floor is obtained by means of lifts and conveyors. This cart area is laid in asphalte, graded so as to be readily hosed down. There is ample space for ingress and egress of traffic from the street, the gateways being fitted with collapsible "Bostwick" gates, which, when open, are housed behind the granite columns. It was unfortunate that this area could not be unobstructed by columns, but the limitations of loading on the raft made it necessary to put in columns to distribute the weight from the floors overhead to the structure underneath.

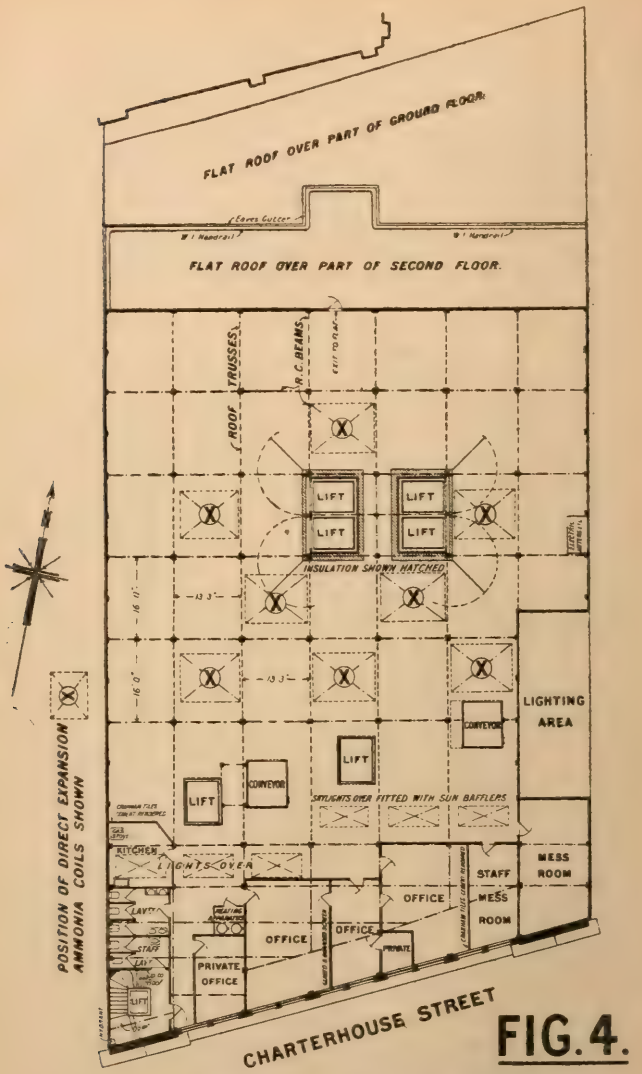
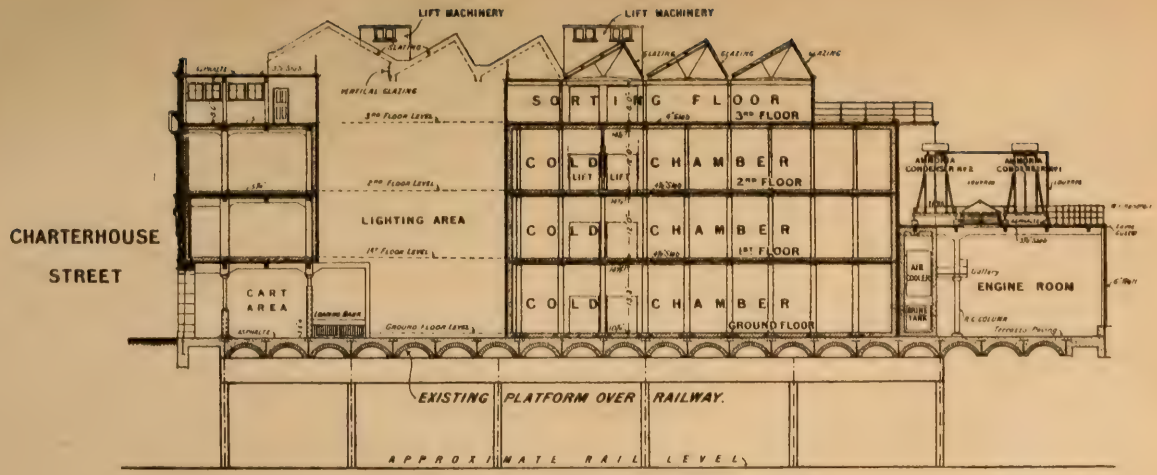


FIG. 4.

THIRD FLOOR PLAN.

SCALE OF FEET.

FEET 10 5 0 10 20 30 40 50 60 70 80 FEET



INSULATION SHOWN HATCHED

FIG. 5. LONGITUDINAL SECTION Y.Z. (SEE FIG. 2).

SCALE OF FEET.

FEET 10 5 0 10 20 30 40 50 60 70 80 FEET

A passenger lift is provided in the stair-well for the convenience of those having business on the top floor.

The top floor, in the main, is covered by a north light roof which has the advantage of affording excellent lighting without letting in the direct rays of the sun and thereby raising the temperature of the sorting floor.

The six cold chambers are arranged so that in normal working, access thereto is obtained only from the top floor. This arrangement has great advantages in economy in running, the cold heavy air being always retained in the chambers, whether produce is being moved in or out, whereas in the old type of chamber with doors or portholes at or near the floor level the cold air pours out and warm air goes in to take its place whenever the doors are opened. Another advantage is that sorting to marks can take place on one floor where there is ample space and good lighting, and under proper supervision. The offices are light and airy, and are divided from each other generally by glazed partitions, the floors being laid in maple blocks so as to afford a non-conducting medium on top of the concrete floor, under which are the cold chambers. Heating of the offices is by low pressure hot water, gas heated. A pneumatic tube for transmission of "delivery notes," etc., connects the main offices with the small delivery office on the ground floor.

It should be mentioned that in each of the three cold chambers there is a door at the south-western corner which can be used in case of emergency; these doors are readily opened from the inside, but access from the outside can only be obtained by means of a key which is kept in a glass-faced box near by.

The total contents of the chambers are approximately 386,900 cub. ft., and after making due allowance for the dead loads, the total number of carcases of sheep, taken at an average of 56lbs. per carcase, which can be stored is 78,000 (equivalent to about 4.99 cub. ft. per carcase, including gangways), distributed as follows :—

Ground Floor ...	...	21,700 carcases.
First Floor ...	...	28,150 ,,
Second Floor ...	...	28,150 ,,
Total ...	...	78,000

If the building had been required strictly to conform

to the regulations made under the London Building Acts, the floors would have had to be designed to carry "warehouse" loads of 224lbs. per sq. ft. This would have so greatly reduced the allowable live loading that the storage capacity would have been reduced below the point at which the Stores could be made to pay. As it is, the ultimate capacity of the Store is some 6,000 carcases less than was originally anticipated, when negotiations with the Corporation were first entered into.

THE CONSTRUCTION OF THE BUILDING.

Tenders for the construction of the building were received towards the end of July 1912 on outline designs, specifications, schedule of prices and approximate bill of quantities prepared by the Port Authority.

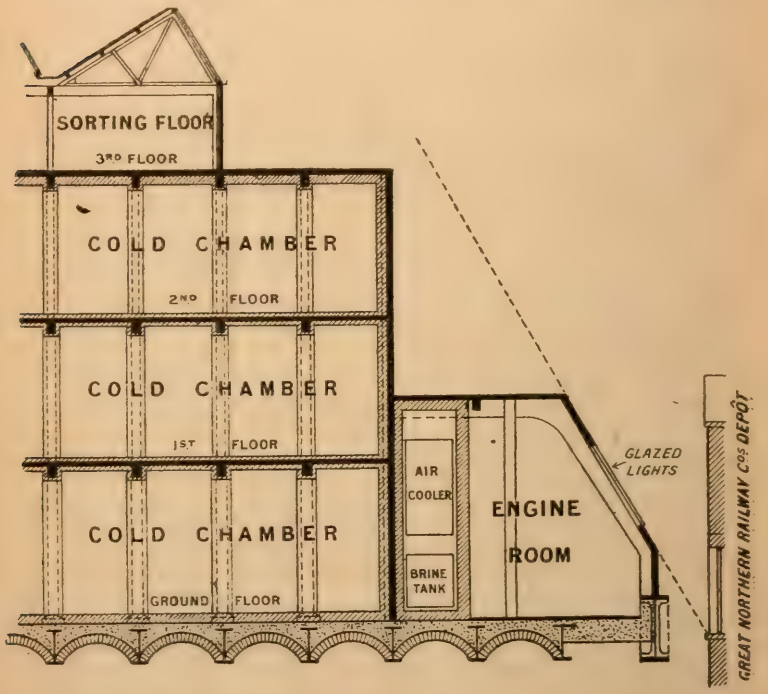
The tenderers were free to submit any system of reinforcing which they considered most suitable and, under the contract, were to be held responsible for the sufficiency of their designs. They were not permitted to make any variation from the positions of the columns and beams, and were required to conform strictly to the limits of loading specified. Owing, however, to unforeseen delays, arising mainly out of the difficulties in settling the question of loading and storage capacity, it was not possible to accept any tender until May of the following year, when the order was placed with Messrs. Trollope & Sons and Colls & Sons on designs prepared by Dr. Oscar Faber.

Instructions were given to proceed with the work in June 1913, after detail drawings had been submitted to and approved by the Port Authority, the Corporation, and the Railway Companies concerned. The time for completion provided in the contract was 33 weeks, but unfortunately, during the period which ensued, considerable labour troubles occurred in the building trades, and this, added to other unforeseen delays, prevented the completion of the building within the contract time.

Prior to actually commencing work on the construction of any of the columns or walls, the surface of the raft was opened up in order to ascertain the exact positions of the main and cross-girders on which the concentrated loads were to be placed.

Owing to the necessity for obstructing as little as possible the space allowed for the cart area, it was decided to substitute, in place of reinforced concrete, nine solid steel

columns varying from 6in. to 7in. diameter, 12ft. 8ins. long, shod top and bottom with solid steel blocks about 18ins. square by 4ins. thick. These columns were subsequently protected against abrasion damage by oak casing, bound with steel hoops, extending 5ft. above the ground level. On the loading bank the columns were encased in concrete, which was protected against damage, by steel casing extending about 6ft. up.

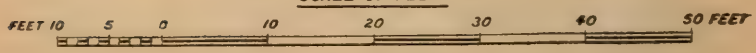


INSULATION SHOWN HATCHED.

FIG. 6.

SECTION V.W. (SEE FIG. 2).

SCALE OF FEET.



Reference has been made to the Great Northern Railway Company's claim to right of light and air. The position of its premises, on the northern side of the site, is adjacent to the west end of the Machinery Room, as will be seen in Fig. 1. The platform already cut off a certain amount of light from the windows, and by constructing the outside wall of the Machinery Room in the manner shown in Fig. 6 the natural lighting was not entirely obstructed. The sloping wall is provided with a large glazed area, which affords a considerable amount of the natural lighting to the Machinery Room; further lighting, as well as ventilation, is provided by two raised skylights fitted with louvres.

Portions of the second and third floors are also covered with flat roofs, but the main area of the latter is covered with Bangor slates on thick roofing felt laid on 1in. boarding and supported by steel trusses. These trusses are carried on reinforced concrete construction built up for that purpose above the top floor level.

As in most building work in London, the site, except for the addition of a small portion of the public footway, also formed the Contractor's Yard, where all materials and appliances, offices and conveniences required during the construction, had to be placed. One of the lift wells formed a very convenient site for an electrically-operated temporary liit, which was retained until the space was required for the erection of the permanent lift.

The specification required the contractor to provide in his design for all columns, counterforts, and pilasters being constructed in the precise positions shown on the outline drawings, and beam construction was restricted in the main to a direction transverse to the length of the building. The walls were specified to be 6ins. thick.

In designing the reinforced concrete work the weight of the reinforced concrete was taken at 150lbs. per cub. ft. and insulating materials at 18lbs. per cub. ft.

The live loads to be provided for were 40lbs. per sq. ft. on a horizontal plane for the pitched roof (this included the dead load of the roof itself), 56lbs. per sq. ft. on all flat roofs, 1½cwts. per sq. ft. on first and second floors, and 1 cwt. per sq. ft. on the third floor. All walls were to be considered as subject on each side to a uniform pressure of 40lbs. per sq. ft. over the whole area. The worst possible combinations of the above loadings were to be taken in arriving at the maximum stresses. Generally speaking, the methods and formulæ outlined in the second report of the

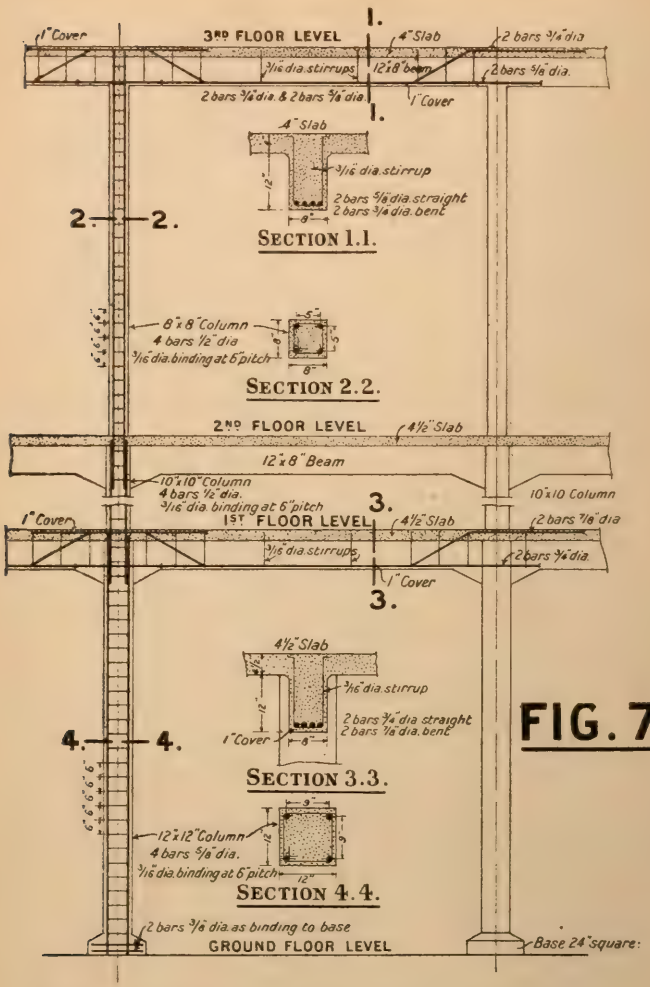


FIG. 7.

REINFORCED CONCRETE DETAILS.

SCALE OF FEET.

INS. 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 FEET

SCALE FOR SECTIONS.

INS. 12 9 6 3 0 1 2 3 4 5 FEET.

R.I.B.A. Joint Committee on Reinforced Concrete, dated 1911, were to be adhered to.

For the purpose of ready reference, Appendix I. has been added, giving the method recommended of ascertaining the bending moments and the working stresses to be adopted.

The concrete for the reinforced concrete construction was composed of clean crushed Thames ballast passed through a ¾in., and retained on a ⅛in. screen mixed with Ham River grit in the proportion of 2 to 1 with latitude for variation when necessary so as to ensure the whole of the voids being properly filled. The cement used was in the proportion of one bag of 224lbs. to every 4½ cub. ft. of sand, and complied with the requirements of the British Standard Specification, the initial set being between 50 and 90 minutes and the final set between 5 and 7 hours.

The beam moulds were so arranged that the sides were readily removed without disturbing the bottom until the beam was sufficiently set, the camber allowed for in the moulds being 1/300th to 1/360th of the span, according to the dimensions of the beam. The column moulds were all arranged with one open side, and this was built up as the concreting proceeded. The steel reinforcing bars were of plain circular sections, having an ultimate strength of 28 to 30 tons per sq. in., an elongation of not less than 20 per cent. in 8ins., and otherwise generally conformed to the British Standard Specification. These bars were covered with at least 1in. of concrete in the case of beam columns, etc., and ½in. in the case of the floor slabs, except where such slabs were in contact with the insulation, when not less than 1in. cover was provided.

The minimum time allowed before removing the supports from the reinforced concrete was, in the case of the main beams and floors, 14 days, and in the other cases 8 days.

The maximum test loads to be applied to the floors and beams provided for an excess of 50 per cent. over the live load for which the particular portion of the structure was designed, and the resulting deflection was not allowed to exceed 1/600th of the span.

Fig. 9 gives particulars of the areas tested, with the results as recorded.

Reference was made in the earlier part of the paper to the granite and Portland stone facing on the Charterhouse Street side. The lower portion of this facing was executed

in Cornish granite, fine axed, and consists of piers and arches forming the entrances and exits to the cart area and main entrance. This granite work was carried up to the level of the first floor, above which rubbed Portland stone facing from the Whit bed was used. This facing work, which varies from 3ins. to 6ins. in thickness, is backed by the reinforced concrete wall, for which it formed the outer shuttering.

Some doubt was felt as to the possibility of the Portland stone becoming stained as a result of the gradual absorption of some of the constituents from the cement in the concrete backing. The usual method, however, of avoiding this trouble, by covering the surface of the stone with limewash, could not be applied, as it was most essential to obtain as complete a bond as possible between the two materials. It was accordingly arranged that, before placing the concrete, the stone should be thoroughly wetted and allowed to absorb as much water as possible, after which the concrete, mixed with as little water as possible, was filled in behind and well rammed. The effect was that, in setting, the concrete tended to draw moisture from the stone, and not, as would otherwise have been the case, the stone drawing moisture from the concrete by capillary attraction.

The result up to the present has been most satisfactory, no appearance of cement staining being visible.

It will be readily understood that the erection of a building of this description, which contains so much machinery and so many appliances as well as insulation of the cold chambers and cold air circulating arrangements, was not by any means a straightforward matter, and it was necessary in consequence to provide a ready means of access both for the erection of the refrigerating machinery at the rear of the building and for the fixing of the insulation, etc., inside the chambers. This was allowed for by temporarily omitting two panels in the walls of the ground floor, one adjacent to the loading bank and the other immediately opposite in the wall separating the Machinery Room from the Cold Chamber. These openings were subsequently filled up when the need for them had disappeared. In anticipation, however, of possible future difficulties in getting long scantlings into the cold chambers should the necessity ever arise, it was decided to construct a porthole in the wall adjacent to the loading bank. This porthole can readily be reopened and long scantlings passed directly through into the Cold Chamber from the street level, and thence up through one

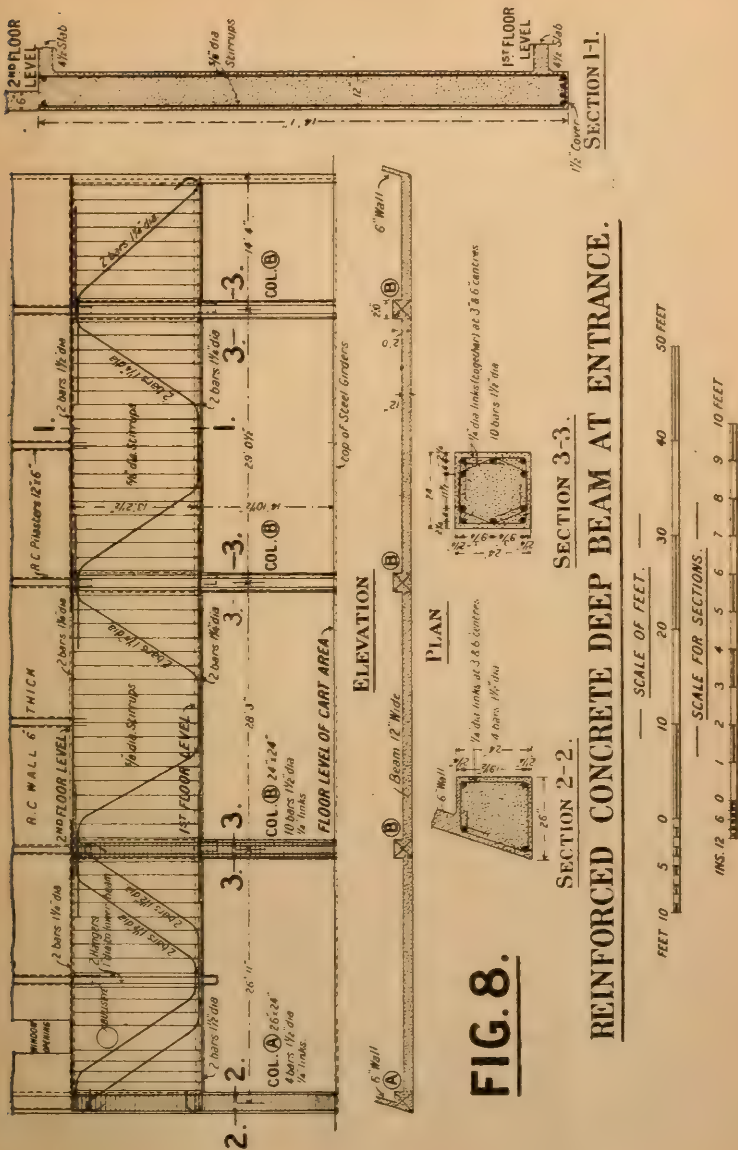


FIG. 8.

REINFORCED CONCRETE DEEP BEAM AT ENTRANCE.

of the lift wells to any of the upper floors; a properly framed insulating plug is provided on the inside over this porthole, so that the insulation will not have to be cut into.

One of the noteworthy features is the way in which the loads at the front of the building are carried. Owing to the peculiarities of the design of the platform on which the building rests, the front columns supporting the building could only be placed in certain positions, which vary from 27ft. to 29ft. centres; although above the first floor, columns had to be provided at about 15ft. centres to keep down the depth of the beams.

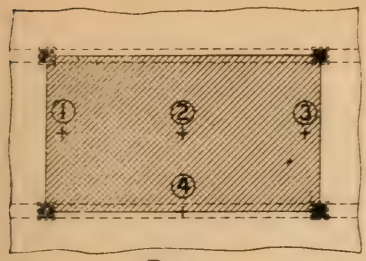
To meet this, a continuous reinforced concrete beam was constructed along the whole front, 14ft. deep and 12ins. thick, completely filling the panel between the first and second floors, and carried on three reinforced concrete columns. Under the centre of each of the three spans a granite column was constructed purely for architectural effect, exactly similar in appearance to the granite-faced reinforced concrete columns which carry the large beam, but no weight is taken by them on account of the loading restrictions. These columns are calculated to carry a load of 355 tons, which is transmitted directly on to steel girders without any footings. Details of the large beam and columns are given in Fig. 8.

The steel columns in the cart area, referred to earlier in the paper, are continued above as concrete columns, as the necessity of reducing their dimensions to a minimum did not arise. Under London County Council Regulations, this arrangement would have been impossible, as the requirements of the Building Act in respect of steel-frame construction and the Reinforced Concrete Regulations cannot be applied at the same time in any one building.

The absence in the reinforced work of cracks due to the large divergence of temperatures to which the structure is subjected is remarkable, but is no doubt due to the effect of the insulation, although the outside of the walls is cold to the touch.

Beyond these special points there is little that calls for remark in respect of the reinforced concrete work.

Fig. 7 gives typical elevations and sections of beams and columns.



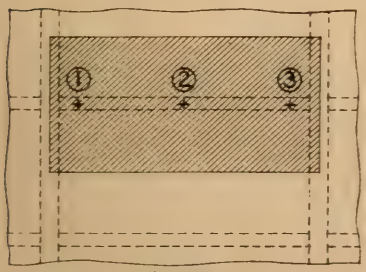
PLAN.

ELEVATION.

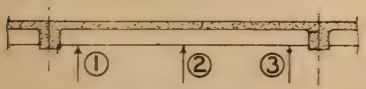
DEFLECTION.

	POINTS			
	1	2	3	4
NORMAL LOAD = 168 LBS. PER SQ. FT.	5/32"	3/16"	5/32"	1/16"
50% ADDED = 252 LBS. PER SQ. FT.	13/32"	9/16"	3/16"	5/32"
WITH LOAD ENTIRELY REMOVED.	0	0	0	0

FIG. 9.



PLAN.



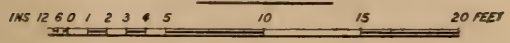
ELEVATION.

DEFLECTION.

	POINTS		
	1	2	3
NORMAL LOAD = 168 LBS PER SQ FT	11/32"	13/32"	1/4"
50% ADDED = 252 LBS PER SQ FT	9/16"	5/8"	3/8"
WITH LOAD ENTIRELY REMOVED.	0	0	0

TEST LOADS ON FLOORS.

SCALE OF FEET.



REFRIGERATING MACHINERY AND INSULATION.

The system which has been installed is known as the Cold Air circulation system. This has several advantages over the Direct Expansion Pipe and Brine Pipe systems which are sometimes adopted. With the air circulation system, where there are several cold chambers, the cooling power of the machines can always be efficiently concentrated on one or more chambers; this is not possible with either of the other two systems. In the latter cases the cooling pipes in the chambers which are not being used are out of commission, and on that account the cooling plant will work less efficiently owing to the reduced cooling surfaces.

The surfaces for cooling the air are always maintained in a maximum state of efficiency, due to the brine passing over them preventing the accumulation of snow, which would otherwise interfere with their efficiency, and which, in the case of the Direct Expansion and Brine Pipe systems, has to be removed by hand.

In this particular case the air circulation system reduces very materially the weight of the refrigerating equipment in the chambers, as the air ducts are very much lighter than direct expansion pipes or brine pipes would have been.

The system used is the Lightfoot Ammonia Compression system, in which the low temperatures are produced by the expansion of anhydrous ammonia. The ammonia gas, in the first place, is compressed by suitable compressors into the ammonia condensers, where liquifaction of the ammonia takes place owing to the cooling action of the water circulating over the outside surfaces of the condenser coils. After passing through a suitable regulating valve into the expansion or brine cooling coils, the ammonia is allowed to re-expand, the reduction in pressure reconverting the liquid ammonia into ammonia gas and resulting in a reduction in temperature of the expansion coils placed in trays, from which the brine is circulated over the air-cooling plates.

The general lay-out of the machinery is shown in Fig. 2, from which it will be seen how the component parts are distributed over the floor, so that the loading should not exceed the limits referred to in the earlier part of this paper.

The ammonia compressors, which are in duplicate, are horizontal double acting with pistons 14ins. diameter and 28ins. stroke, running at a speed of 55 revolutions per minute. A total speed variation of 25 per cent. is provided for, and extra large suction and delivery valves were specified

so as to allow ample margin for increase in output. Owing to the fact that the brick arches of the platform supporting the machines could not be cut into, and also for the purpose of distributing the loads, it was necessary to provide two heavy flywheels to each machine. For the accommodation of these flywheels, which are 10ft. diameter and 25ins. and 15ins. wide respectively, it was arranged to cut a recess about 1ft. deep in the concrete filling of the platform and in addition the machinery bedplates were made deeper, thus saving the extra weight of higher concrete foundations. The foundation bolts of the main machinery are carried right through the platform, and the stresses from them are distributed directly on to the underside of the cross-girders of the platform by channel irons.

The electric motors, which drive the compressors through 24in. continuous "Roko" belting, are each 150 B.H.P. of the self-ventilating type, compound wound for a voltage of 530 continuous current, and running at 200 revolutions per minute.

Each unit is capable of keeping all the chambers at a temperature of 10 deg. Fahrenheit when the outside temperature does not exceed 75 deg.

The ammonia condensers or cooling coils are placed in duplicate on the roof of the Machinery Room (see Fig. 5), and each consists of about 4,720ft. run of iron pipe $1\frac{2}{3}\frac{9}{2}$ ins. external diameter. Water for cooling is pumped over the ammonia condensers from trays immediately under them by two independent 4in. electrically-driven centrifugal pumps, each capable of discharging 300 gallons per minute and having a speed variation of 25 per cent. The coils are protected by timber louvred screens to prevent loss of water by the action of wind, and are supported directly on the trays above referred to.

The air-cooler batteries, also in duplicate, were specially designed to suit the requirements of this Cold Store, and each consists of a series of vertical corrugated galvanised steel plates having a total superficial area of 27,500 sq. ft., arranged over a wrought-iron collecting tray and having above them a series of perforated steel trays, into which a constant stream of cold brine is delivered by means of an electrically-driven centrifugal circulating pump. This pump draws the brine from the wrought-steel tanks placed below the trays, in which are placed about 5,420ft. run of $1\frac{1}{2}$in.

external diameter Ammonia Direct Expansion coils, arranged with suitable baffles to ensure efficient circulation of the brine round the cooling coils.

Air is blown by means of suitable electrically-driven propeller fans between the corrugated plates, where it loses its latent heat and thence passes through a system of air trunks into the cold chambers, from where it returns to the batteries to be again cooled and returned to the chambers.

The fans for circulating the air through the batteries are of the "Sirocco" type, 55ins. in diameter, running at 175 revolutions per minute, each delivering about 50,000 cub. ft. of air per minute, and arranged to be driven by belt from a 20 B.H.P. electric motor having a speed variation of 25 per cent.

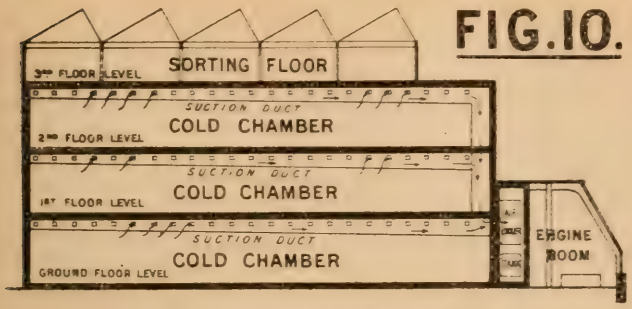
The delivery air trunk from the batteries, which has an internal cross-section of 10ft. 9ins. by 5ft., is contained in a shaft formed in reinforced concrete. Flap valves are provided for shutting off delivery of air from either battery when not in use. A diagrammatical outline of the general arrangement is shown in Fig. 10.

There are six branch trunks connected with the main vertical delivery trunk, and a similar number to the two return trunks, for conducting the air into and out of the cold chambers. These trunks are situated on opposite sides of each chamber immediately under the roof, and extend for the whole length of the sides. The internal dimensions vary from 3ft. 9ins. by 3ft. at one end to 18ins. by 12ins. at the other. They are formed in 1¼in. tongued and grooved boarding and fitted with sliding doors about every 5ft. over air openings 10ins. by 8ins.

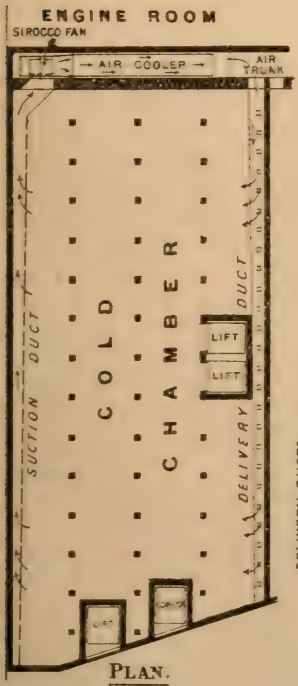
A slide is provided at the entrance to each of these trunks on both the delivery and return sides, so as to enable any chamber to be completely cut off from the cold air supply and also to assist in regulating the supply. The batteries and vertical air trunks are insulated where they come in contact with external temperatures.

The top or sorting floor is fitted with about 2,000ft. run of 1¼in. by 1⅝in. iron piping for direct ammonia expansion, should it be desired at any time to reduce the temperature of this floor. The piping is divided into four sections for the purpose of control of temperatures, and is supported from the reinforced concrete beams overhead. Up to the present, however, there have been only one or two occasions on which this part of the system has been used.

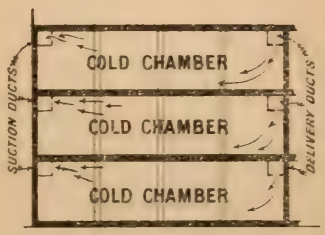
FIG. 10.



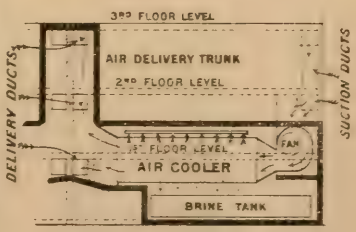
LONGITUDINAL SECTION.



PLAN.



CROSS SECTION OF CHAMBERS.



SECTION OF COOLING PLANT.

DIAGRAMS OF COLD AIR CIRCULATION.

INSULATION.

Before applying the insulation, and whilst the building contractors were in possession, the interior of all the outside walls, except that on the east side, was asphalted with ¾in. Limmer asphalte put on in two layers. This precaution was taken against the possibility of any moisture condensing on the insulation where it comes in contact with the concrete.

The extra cost involved was not considerable in view of the fact that it removed the risk of ice forming in the silicate cotton insulation. Should such a thing happen, the value of the insulation is seriously reduced and great expense has to be incurred in cutting out and making good the damage, besides losing the accommodation and revenue during the time repairs are being executed.

With the exception of the insulation of the doors to the lift openings on the top floor and the doors in the partitions separating the chambers on the ground, first, and second floors, the whole of the insulation is of silicate cotton filled in between timber "grounds" and boarding.

The "grounds" of the roofs of the ground and first floors are 4ins. by 3ins. spaced 24in. centres, and that of the second floor 8ins. by 3ins.—24in. centres, the boarding being ¾in. tongued and grooved first lining and 1in. tongued and grooved second lining.

In the case of the ground and first floors, the "grounds" are 10ins. by 3ins.—15in. centres and the second floor 3ins. by 3ins.—15in. centres, with the first and second lining in each case of 1in. by 1½in. tongued and grooved boarding.

The partitions are formed of 8ins. by 2ins. "grounds" spaced 18in. centres, with two layers of 1in. tongued and grooved boarding on each side. Waterproof paper is laid between the two linings in each case and the silicate cotton packed tight into the intervening space, the specified weight being between 16 and 18lbs. per cub. ft.

All insulated doors were strongly framed in pitch pine, those to the lift opening and partitions being insulated with two layers of 3in. compressed cork slabs with two layers of 1in. tongued and grooved boarding on each side. The emergency doors were insulated with 8ins. of silicate cotton with similar boarding on each side. The taper of the four sides of the doors was made 3 to 1 and lined with "Fear-

nought." The doors are hung on special galvanised iron hinges made by Messrs. Taylor, who also supplied the door-tightening gear.

The timber used in forming the insulation was best quality Burnettised Swedish white wood. After completion, the whole of the exposed timber surfaces, except the floors, received two coats of Shellac varnish.

Dunnage battens 2ins. square, extending from floor to ceiling, are secured to the walls at intervals of 12ins., and removable division pillars, having suitable sockets for their reception in the floors and ceilings, are provided for separating different parcels of meat when required. These are spaced 8ft. one way and 3ft. the other, and are formed in 4in. square planed and chamfered timber.

Unfortunately, the builders' strike in January, 1914, affected also the insulation work to such an extent that, by the time the building was complete and the machinery ready for running, the first and second floors only had been insulated. To enable the stores, however, to be brought into use, insulated plugs were fitted in the four internal lift wells at the first floor level, so that the work of insulating the ground floor might proceed without being affected by cold from the upper floors.

The whole of the refrigerating machinery is on the Lightfoot system, as supplied by Messrs. The Lightfoot Refrigeration Company, Limited, of London; the insulation of the stores and the installation of the twelve special Leskole long-distance thermometers were executed by the same firm that supplied the machinery.

The whole of the machinery and insulation is in accordance with the requirements of the Institute of London Underwriters and Lloyds, and the Stores as a whole is on Lloyds' List.

EQUIPMENT.

The mechanical appliances for handling the produce consist of two vertical continuous mutton conveyors and six goods lifts.

The conveyors, which extend from the level of the loading bank up to the top floor, are of the finger-tray type, having a capacity of 650 carcases of mutton per hour at a speed of 100ft. per minute, and are driven by 5 B.H.P. electric motors. At the bottom is provided a wooden table inclined towards the conveyor. The carcases are placed on

the table one by one and slide down to, and are retained on stationary prongs arranged so as to miss the fingers of the conveyor trays; from here they are picked up by the next tray as it ascends, and after passing over the top pulleys are landed on a similar series of prongs at the upper level, from whence they slide down on to another wooden table on the sorting floor. From here they are collected for weighing and sorting to mark, etc., and then sent down to the Cold Chambers. The conveyors can be started or stopped by simple push-buttons.

Of the six goods lifts, two outside lifts are arranged so as to afford direct communication between the loading bank and the top floor, and the remaining four afford access between the top floor and the three refrigerated floors, each Cold Chamber being directly served by two lifts. (See Figs. 3 and 4.)

The travel of the external lifts is 37ft. 9ins. and of the four external lifts 40ft. 3ins. Each has a carrying capacity of 3,000lbs. at a speed of 100ft. per minute, and is operated, through worm gearing, by a 7½ H.P. electric motor, the end thrust on the shaft being taken up by double ball bearings. Automatic appliances are provided in case of rope breakage, and there are slack cable and anti-over-winding contrivances which cut out the motor if necessary.

Each cage is suspended by two steel wire ropes, which are attached to the winding drum, the whole of the dead load of the cage being taken up by cast-iron counter-balance weights attached to the drum by two similar ropes.

The cages of the outside lifts are arranged with a door back and front, the former for use at the level of the loading bank and the latter to serve the top floor. The dimensions of these cages are 5ft. 3ins. by 8ft. 9ins., as compared with the internal lifts, which are 6ft. by 8ft., the height being 7ft. in each case.

The operation of the lifts is by small controllers of the tramcar type in the cages, the control panels, which were supplied by the Igranic Company, being placed immediately over the lifts to which they belong.

The lifts are made as nearly "fool-proof" as possible by means of electrical locking gear provided on the lift gates and at the various floors, so that the lift cannot be moved unless all gates are shut, and the gate on any floor can only be opened when the lift is at that particular floor level. The gates are of the double lattice Bostwick Gate Company's make.

Some little difficulties were at first experienced owing to condensation of moisture and rusting of the fine adjusting screws, contacts, etc., but this has now been got over satisfactorily by smothering all such parts in "Arctic" non-freezing oil.

In addition to the gates above referred to, iron fireproof doors are provided to all lift openings in the case of the internal lifts, and Kinnear patent steel rolling fireproof shutters are fixed at the lift and elevator openings at the loading bench level.

The passenger lift, which is operated by an 8 B.H.P. electric motor, has a carrying capacity of 10 cwts. at 170ft. per minute, and can be stopped at the landing level of any floor. The machinery is similar to that of the goods lifts.

For weighing the produce on the loading bank a 20 cwt. flush weighing machine, made by Dennison, is provided about the centre of its length, and on the top floor there are three portable weighing machines, which can be moved about as required.

A number of hand trucks on four wheels complete the equipment. These are of a size which permits of their being run direct into the goods lifts, so that when no sorting has to take place the carcases can be taken in these trucks direct from van to Cold Chamber and *vice-versa* without further handling.

The fire-fighting appliances consist of five 2½in. fire hydrants, one situated at the level of each floor within the stair well and one in the loading yard.

The threshold at each of the lift openings is raised 3ins. above the level of the floor so as to form a water stop which will allow of the various floors being flooded without the water finding its way down to any of the lower floors. Fixed ramps covered with chequered steel plates are provided so that the trucks can be readily pushed in or out of the lifts.

Power and lighting throughout the stores are by electricity, supplied from the mains of the County of London Electric Supply Company, who, owing to the favourable character of the demand, were able to supply current on advantageous terms. In this connection a restricted period was introduced in the terms of the supply prohibiting the use of electricity for driving the refrigerating machinery during the winter peak-load hours of from 3 to 7 p.m. between the beginning of October and the middle of March. There is no difficulty whatever in complying with this

restriction, as it occurs during the period of the year when the external temperatures are low and the amount of work required to be done by the freezers is consequently very much less than in the summer months.

ADDITIONAL SUPPORTS UNDER PLATFORM.

Soon after the Stores were opened for the reception of carcases, and loading commenced several cracks made their appearance in the external walls at the back of the building. From the nature and direction of these cracks it was concluded that they were due to the deflection of certain of the longer main girders forming part of the platform on which the building had been constructed. Further loading on the area affected was thereupon stopped for the time being.

At the north-west corner of the site and under the walls in which the cracks appeared the existence of a locomotive fan turntable and a sewer had resulted in an arrangement of stanchions which necessitated two of the main girders being constructed to spans of 61ft. 10½ins. and 54ft., with an overall depth of 6ft. 8¾ins. and 5ft. 5ins. respectively. Calculations showed that, whilst of ample strength, deflection must occur in these girders to the extent of about 15/32in. and 27/64in. due to the dead loads coming on them, and a further 9/64in. and 11/64in. respectively due to the allowable live loads.

Further, it was ascertained that the deflection varied according to the variation in the number of carcases in the store. In view of the fact that the weather could reach the insulating material unless the cracks in the walls were permanently closed, it became necessary to stop the variation in the amount of deflection of the two girders.

Permission was therefore obtained to erect two additional stanchions under the girders, approximately midway between their points of support. The positions of these are indicated in Fig. 2 by the letters T and S.

The new stanchions, which were built up of rolled steel joists and plates, were designed to carry loads up to 490 tons and 253 tons respectively, and were placed on foundations consisting of grillages of rolled steel joists embedded in 6 to 1 P.C concrete carried down on to the London clay the loads on which were arranged so as not to exceed 4 tons per sq. ft. In the meantime, two 1¼in. steel plates, drilled to template for the accommodation of the rivet heads on the underside of the girders, had been secured thereto with a

layer of 7lbs. lead interposed between the plate and the girder in each case. Two pairs of folding steel wedges, 3ft. 6ins. long by 8ins. wide, with a taper of 1 in 42, were then placed in position on the top of each stanchion and immediately over the flanges of the stanchions, and all four were driven simultaneously from a staging with 14lb. hammers. Previous to driving up the wedges the live loads on the areas carried by the girders in question were reduced as much as possible, and the wedges were driven until the whole of the deflection due to the remaining live load and a small amount of the deflection due to the dead load were taken out, thus preventing the possibility of any further movement in the future.

The stanchions were wrapped with expanded metal and encased in concrete to preserve them against deterioration.

These operations had to be carried on without interfering with the traffic on the railway lines, and for that reason the work could only be done during week-ends between the hours of midnight on Saturday and 6 p.m. on Sunday. Apart from the construction of the stanchions and the taking of templates, the work extended over 15 week-ends. After the completion of this work an internal examination of the condition of the insulation in the neighbourhood of the cracks was made by opening out the linings, but fortunately no deterioration was discovered. The cracks in the walls were accordingly cut out and filled with cement, and no further movement has since been discerned.

The fact that the site of the building was immediately over the railways previously referred to, and on which steam locomotives are constantly passing, was responsible for some difficulties in connection with the protective coatings which had been applied to the exposed metal work on the roof at the back of the building.

A few months after the store had been brought into use it was discovered that the bituminous solution which had been used to coat the ammonia condenser pipes showed signs of deterioration. On testing the water in the trays with blue litmus paper a pink discolouration was produced. It was accordingly decided to have the water analysed. The result of this analysis is shown in Appendix 2, from which the conclusion was drawn that during the passage of water over the coils it absorbed a considerable quantity of SO_3 from the fume-laden atmosphere, which varied with the time

the same water was allowed to remain in use. Eventually it was arranged that the whole of the water in the trays was to be run off and replaced by fresh water from the mains once every month. The analyses of the water taken direct from the mains are shown in columns 7 and 8, and these will be seen to differ very little from the sample of water taken from the trays after being one month in use.

The coils were re-coated with "Bitulin," but as this subsequently failed even under the improved conditions resulting from frequent changing of the water, it was ultimately decided to coat them with Ryland's No. 2 "Titanic" paint.

Similar experience was also met with in the case of the graphite paint which was used on the ungalvanised ironwork. This was found to deteriorate, and as an anti-acid paint appeared to be the only proper class of coating to be adopted, several different makes of such compositions were tried by exposing prepared plates to the effects of the fumes and the moisture in the atmosphere. These plates were hung on the railings immediately over the railway, and test lengths of the railings were also coated with the same compositions. The results of these tests are given in Appendix 3, from which it will be seen that of those compositions tested, and bearing in mind the number of coats which had been applied, Messrs. Llewellyn Ryland's No. 2 "Titanic" paint withstood these particular conditions successfully for over a year, but Messrs. Blundell Spence's "Special Red Protective" has outlasted all the paints tested. This may, however, be due to the fact that four coats were initially applied.

With the exception of the ground floor, the whole of the Stores and equipment were brought into commercial use on August 6th, 1914, and the ground floor added to the Cold Storage accommodation seven weeks later. The additional storage provided just after war broke out proved to be of the greatest value in affording extra accommodation for the glut of frozen meat which flooded the markets at that time.

The whole of the work was carried out under the direction of Mr. C. R. S. Kirkpatrick, M.Inst.C.E., who early in 1913 succeeded Mr. F. Palmer, C.I.E., M.Inst.C.E., as Chief Engineer to the Port of London Authority, the

author holding the position of Chief Assistant Engineer since July, 1913.

Valuable assistance was given by Messrs. Esplen, Son, & Swainston, who acted as consulting specialists in respect to the refrigerating machinery and insulation, and by Mr. T. H. Smith, consulting architect for the building.

The author desires to acknowledge his indebtedness to Mr. W. B. Statham, Assoc.M.Inst.C.E., of Messrs. The Lightfoot Refrigeration Company; Dr. Oscar Faber, D.Sc., Assoc.M.Inst.C.E., Member of the Concrete Institute; and to the various members of the Authority's staff who have rendered valuable assistance to the author in the preparation of this paper.

Lastly, the author wishes to put on record the great loss which the Port Authority, as well as the engineering profession, have sustained in the death of Mr. Arthur Poynting, who was killed in action on July 26th, 1916. Mr. Poynting, who acted as Resident Engineer from the commencement of the work until he joined His Majesty's Forces in August, 1914, showed rare talent and great promise for the career he had chosen, and, moreover, possessed a character which endeared him to all those with whom he came in contact.

APPENDIX 1.

For the purpose of ascertaining the bending moment, the effective spans of the various members to be taken as follows :—

(1) For all beams (whether continuous or supported) the distance from centre to centre of bearings.
(2) For slabs supported at the ends, the clear span plus the thickness of slab.
(3) For slabs continuous over supports, the clear span plus twice thickness of slab, or distance from centre to centre of bearings (whichever is the least).

The bending moments to be calculated by ordinary statical principles in every case. In the case of slabs and beams continuous over supports at both ends and subjected to uniformly distributed loading, the bending moment to be

taken as $\frac{WL}{12}$ at centre of span and $-\frac{WL}{12}$ at supports.

In the case of similarly loaded beams or slabs continuous at one end and supported only at the other end, the bending moment to be taken as $\frac{WL}{10}$ at centre of span and $-\frac{WL}{10}$ at supports.

(Where W = total load and L = span.)

The bending moment on slabs supported on all four edges may be reduced according to the rules of Grashoff and Rankine, as set forth in Appendix VIII. to the R.I.B.A. second report.

The following working stresses in no case to be exceeded under the maximum possible conditions of loading and on the basis of an ultimate compressive stress of not less than 1,800lbs. per sq. in. of concrete after setting for 28 days :—

Concrete in compression ...	600lbs. per square inch.
,, ,, shear in beams	60lbs. ,, ,, ,,
,, ,, tension ...	Nil lbs. ,, ,, ,,
Adhesion of concrete to metal	100lbs. ,, ,, ,,
Steel in tension	16,000lbs. ,, ,, ,,
,, ,, compression ...	15 times the stress in the surrounding concrete.
,, ,, shear	12,000lbs. per square inch.

APPENDIX 2.

ANALYSIS OF WATER FROM AMMONIA CONDENSERS.

1	2	3	4	5	6	7	8
IMPURITY.		Sample taken from No. 2 Tank after 6 months.	Sample taken from No. 1 Tank after 6 months.	Sample taken from No. 2 Tank after 2 months.	Sample taken from No. 1 Tank after 1 month.	Sample taken from Ball Tap No. 1 Condenser 3/2/15	Sample taken from Ball Tap No. 1 Condenser 11/1/15
		Grains per Gallon.	Grains per Gallon.	Grains per Gallon.	Grains per Gallon.	Grains per Gallon.	Grains per Gallon.
Silica	SiO_2	1.64	1.29	0.70	0.45	0.41	0.29
Ferric Oxide and Alumina ...	Fe_2O_3 / Al_2O_3	0.22	0.41	0.17	0.25	Trace	0.11
Lime	CaO	47.81	40.60	31.22	10.37	9.62	8.62
Magnesia	MgO	2.77	2.45	1.86	0.98	0.50	0.45
Soda	Na_2O	9.94	9.38	9.40	4.45	1.79	2.51
Carbonic Anhydride	CO_2	1.32	2.56	3.92	5.73	6.91	6.44
Sulphuric Anhydride	SO_3	74.90	60.06	38.33	7.59	2.26	1.50
Chlorine	Cl	8.97	7.90	5.65	3.45	1.33	1.33
Nitric Anhydride	N_2O_5	—	—	6.75	—	—	1.35
		147.57	124.65	98.00	33.27	22.82	22.66
Deduct Oxygen equivalent to Chlorine		2.02	1.78	1.27	0.78	0.30	0.30
		145.55	122.87	96.73	32.49	22.52	22.36
Combined Water and Organic Matter		31.13	25.53	15.29	3.35	3.38	0.74
TOTAL SOLIDS		176.68	148.40	112.02	35.84	25.90	23.10
PROBABLE SALTS.							
Calcium Carbonate	$CaCO_3$	3.00	4.57	8.91	13.02	15.70	14.64
Calcium Sulphate	$CaSO_4$	112.03	93.89	63.68	7.48	2.01	1.02
Magnesium Sulphate	$MgSO_4$	8.31	7.14	1.31	2.94	1.50	1.35
Magnesium Nitrate...	$MgNO_3$	—	—	1.23	—	—	—
Sodium Chloride	NaCl	14.78	13.02	9.31	5.69	2.19	2.19
Sodium Sulphate	$NaSO_4$	4.83	—	—	2.18	—	—
Sodium Nitrate	$NaNO_3$	—	—	9.51	—	—	2.13
Fatty Acids	—	0.81	2.35	—	—	—	—

APPENDIX 3.

TESTS OF PROTECTIVE COATINGS.

Maker.	Description of Paint.	No. of Coats.	Condition after 1 months' exposure.	Condition after 12 months' exposure.	Condition after 2 years' exposure.
Blundell Spence ...	"Special Red Protective"	4	Good.	Fair.	Fair.
Blundell Spence ...	"Black Protective" ...		Unsatisfactory.	Deteriorated.	Destroyed.
Llewellyn Ryland ...	"No. 1 Titanic" ...	2	Good.	Beginning to deteriorate.	Destroyed.
Llewellyn Ryland ...	"No. 2 Titanic" ...	2	Excellent.	Excellent.	Destroyed.
Tockolith, Ltd. ...	"Tockolith" and "R.I.W.49" ...	1 / 1	Good.	Deteriorated.	Destroyed.
Tockolith, Ltd. ...	"Tockolith," "R.I.W.1375" and "R.I.W.49" ...		Unsatisfactory.	Deteriorated.	Destroyed.
Walles Dove ...	"Bitumastic" ...	2	Good.	Destroyed.	Destroyed.
Pinchin Johnson ...	"Red Protective" ...	2	Very good.	Very good.	Destroyed.
Pinchin Johnson ...	"Black Protective" ...		Unsatisfactory.	Deteriorated.	Destroyed.
London Flambo Fuel Company	"Cuirass"		Unsatisfactory.	Deteriorated.	Destroyed.
W. Briggs	"Tenax Bituminous"		Unsatisfactory.	Deteriorated.	Destroyed.
W. Briggs ...	"Ferroid Bituminous Enamel"		Not good (cracked).	Deteriorated.	Destroyed.

DISCUSSION.

The Chairman proposed a hearty vote of thanks to the author for his excellent paper.

Sir Henry Tanner, C.B., I.S.O., P.-P.C.I., who was asked to open the discussion, heartily endorsed the vote of thanks which had been proposed by the Chairman. The construction seemed to him to be remarkably good, and reinforced concrete seemed most useful for the purpose.

Mr. A. T. Walmisley, referring to the remark in the paper that the site was the least desirable, said he supposed the author meant because of its limited area coupled with the prescribed limit of super-imposed loads which had to be dealt with, because as regards the position on the map and of the railways underneath, the site was not so very undesirable. As regards the additional stanchions that had to be put in, when the floor crossing the sub-structure was built for the Corporation, there was not the slightest idea as to the nature of any building that might be placed upon this site. The site stood as a floor covering the railways containing a certain amount of strength and was well tried before it was decided to put up a four-storey building upon it. The two additional stanchions were required because of the nature of the building adopted on this site, and would not have been necessary with a building of the warehouse type. He would like to pay a tribute to the courtesy that was paid by the Port of London engineers and their contractors to the Corporation representatives whilst the work was in progress. They were at all times willing to shew the Corporation representatives over the works and to deal with any details that were asked for.

Mr. C. R. S. Kirkpatrick, M.Inst.C.E., said that much of the success of the building was due to the skill with which Mr. Deane carried out the work. There was one point of interest which struck him. When the building was first started it was contemplated that a cold store capable of holding 84,000 carcases would be erected, but owing to the restrictions on loading the number of carcases was reduced to 78,000. Then a claim was put in by the District Surveyor that the building came under the London Building

Regulations. In that event it could not have been built in four storeys as it would have had to be in brickwork. It would have had to be three storeys on account of the restrictions of the Corporation owing to the raft and to the fact that the building had to be built on the top of two tunnels. Investigating the position as to reinforced concrete it was found that the regulations under the 1909 London Building Act had to be approved by the Local Government Board, but that approval had not been received. The London County Council, however, did not raise any objection to reinforced concrete if the building complied with those regulations, viz., 2cwts. per square foot for each floor. Once again they found themselves in the difficult position that if these conditions were complied with, the cold store could not be built except unprofitably from the financial point of view. Further search was made and rather interesting circumstances were revealed. When the ground landlords (the City Corporation) obtained powers in 1875 for building the Central Markets, they had an exemption under the Metropolis Building Act of 1855 for all buildings on the market site. When the London Building Act of 1894 was passed, no mention was made of this exemption, and on going into the matter it was found that the cold store was on the market site and could claim the benefit of this exemption. As a result the Authority were able to put up a building with nothing like the loading requirements of the reinforced concrete regulations under the 1909 Act. The building therefore had the four floors contemplated with a capacity of 78,000 carcases. This matter was of some interest because it shewed that the London Building Act at that date prevented the development of the use of reinforced concrete for building purposes where the load was not actually 2cwts. per square foot. On the question of what the building cost, it was never possible to compare one building with another. This work was pre-war work, and it must be borne in mind that there was no cost in connection with the foundations; but excluding that, the cost came out at 2s. 4d. per cubic foot of refrigerator space, including machinery, which was equivalent to 11s. 9½d. per carcase of mutton. Another point was the satisfactory way in which the contractors carried out the reinforced concrete work and designed the details. He would like also to reciprocate what Mr. Walmisley had said about the Port of London Authority. The courtesy was not all on the Authority's side, because the City of London Corporation was extremely courteous throughout.

Dr. Oscar Faber, D.Sc., M.C.I., said that one of the things that required a certain amount of consideration in the early stages was the likelihood of contraction and cracking in the walls owing to the very great reduction of temperature inside, and a certain amount of discussion took place as to how much reinforcement would be required for the walls. He himself came to the conclusion that it affected the question very little, and ultimately very little reinforcement for the walls was used. With the exception of the back of the building where the supporting girder deflected nearly ½in., there was no question of cracking or contraction of the walls. He entirely endorsed what Mr. Kirkpatrick had said with regard to the L.C.C. reinforced concrete regulations and their effect on the development of this class of building. Under the regulations the floors should be designed for 224lbs. per foot, but they were designed actually for 168lbs. in the case of some, and 112lbs. in the case of others. The walls carrying the four storeys were only 6ins. thick; yet although under the regulations 6in. walls could be used as panels, they could not be used for carrying the load, but they had proved in this case absolutely sufficient for the task. At the same time it was not everybody that was in the position of the Port of London Authority in their power of evading the Building Acts, and in these times of financial stress it would perhaps be well to consider whether such very large sums of money ought to be allowed to be wasted as were involved in complying with the regulations, simply because they could not be made a little more reasonable. Attention had been drawn to the Portland stone attached to the front of the building through which the cement had not penetrated. The method adopted was due to Mr. Deane himself and it had proved most successful. One frequently saw cases where the whole front of the building was ruined by the patches of white crystals which were formed through the cement penetrating. His own idea had been to put a waterproof composition against the Portland stone, but Mr. Deane's method was much simpler. As regards the bending moments of the beams, these were in accordance with the specification, but they were rather arbitrary. A bending moment of WL/12 in the centre of the beam under the conditions which prevailed could have been reduced, and he suggested that greater latitude might be given to designers in that respect. At the same time, he agreed that in a structure like this, in which there was a deflection in one of the supporting girders of as much as

½in., considerable additional stresses came upon the structure and in many cases these stresses were at least equal to the stresses due to the load, and they must be taken seriously into account. With regard to reinforced concrete generally, if one followed the regulations, his opinion was that they tended to give too strong beams and too weak columns. That opinion he had verified by a very complete series of tests both on beams and columns in testing machines where the actual factors of safety had been demonstrated. In the front of the first floor of the Charterhouse Street building, maple flooring was adopted, but the precaution was taken of leaving a margin of ¾in. all round to allow for expansion. Maple blocks expanded considerably when they got wet, and this floor got very wet. As a matter of fact, the floor swelled over ¾in., buckled, and had to be made good, and it would rather appear that the maple floor was a dangerous thing to use in a cold store, although it had good wearing properties.

Mr. W. B. Statham, Assoc.M.Inst.C.E., referred to the method for starting up the compressors. The special by-pass was a great improvement over the loose pulley, which was generally used in the old days. The ammonia condensers were designed specially to economise water, which was a great consideration where water was scarce or had to be paid for. Further, the condensers had been designed so that they were easily accessible, a specially valuable feature on account of the corrosive effect of the air in this particular location. It might be interesting to know that with an average ammonia evaporating temperature of 10 degrees, the total heat eliminating power of the two compressors is equal to 1,800,000 to 2,000,000 British thermal units per hour, and if they were devoted to making ice, the two compressors would be capable of producing 72 to 82 tons of opaque can ice per twenty-four hours.

Mr. T. C. Dawson, M.C.I., said he was very interested in the extra stanchions which had to be put in, with which he had to deal on behalf of the Corporation. He was further very greatly interested in the 7lb. lead packing on the two new stanchions, and he wondered whether subsequent observation would shew that this had been reduced to the thickness of tinfoil.

Mr. Deane, replying to the discussion, expressed his thanks for the manner in which the paper had been received. He thought this was going to be a very small job when he

first started, but he found to his cost that it involved a very great deal more time and labour than was originally anticipated. He thanked Mr. Walmisley for his remarks and endorsed what Mr. Kirkpatrick had said on the other side as to the relations which existed between the Port of London Authority, the City Corporation and the contractors. Dr. Faber had criticised the bending moments which were in the specification. He did not know that he had very much to say on that subject, but if the formula for the bending moment had been reduced, probably a little more concrete would have been asked for to protect themselves against the possibility of the effect of the cold on the reinforced concrete structure, and he did not think the sum total would have meant very much in carcases, because after all carcases were the things for which the storage existed. The protection of Portland stone from the action of cement and water had been rather a hobby of his. He had seen many buildings where the Portland stone had been absolutely ruined by the use of Portland cement. The method adopted in this case was that used in the case of the Kingston Bridge, with which he had had the honour of being intimately connected at the time it was widened four or five years ago. The old bridge was widened from 28ft. to 55ft. and a great deal of old work had to be cut out on one side. The old bridge was constructed of Roman cement brickwork and Portland stone, whilst the new work was of Portland cement brickwork and Portland stone. He tried all sorts of methods of getting rid of the trouble in question, and the one adopted at Charterhouse Street was found to be the best. As to the maple flooring, he had had some experience of that before. It was very hygroscopic, and sucked up any moisture there was about. The three inches space referred to by Dr. Faber was only 1½ inches all round, but if he were laying down that flooring again he would allow three inches all round. Once it was settled down, that flooring never gave any further trouble. The criticisms of the L.C.C. regulations as regards loads were very just. The point in favour of the design adopted as against one complying with the building regulations is that the building is standing to-day. There was no sign of it giving way anywhere, and if the building regulations were the minimum, it seemed to him there was something wrong somewhere. Mr. Statham had added some valuable information to that which had already been published. As to Mr. Dawson's remarks, the lead packing was put in because the underside of the existing girders,

which form part of the raft, was necessarily rough. The girders were pitted with rust and had not been planed, and in order to be sure of getting a good bearing between the top of the columns and the underside of the girders, some sort of adjustable packing was regarded as necessary, and lead was put in. There was no special virtue about the lead being 7lbs., except its thickness. The girder encased in concrete, referred to by Mr. Leverton, forms part of the original raft on which the building is founded. Several experiments were made on the weight of carcases to see exactly how many carcases could be loaded on the floors, and from these tests it was found that New Zealand sheep weighed about 24lbs. per cubic foot of space occupied, beef 20.28lbs., and the space occupied by one sheep carcase was 2.266 cubic feet, and by a quarter of beef 7.554 cubic feet. The average weight of the sheep was 54.4lbs., and that of a quarter of beef was 153.2lbs.

The meeting then terminated.

NINTH ANNUAL GENERAL MEETING AND EIGHTY-FIRST ORDINARY GENERAL MEETING.

THURSDAY, MAY 9, 1918.

THE NINTH ANNUAL GENERAL MEETING and THE EIGHTY-FIRST ORDINARY GENERAL MEETING of the CONCRETE INSTITUTE were held on Thursday, May 9th, 1918, the retiring President, Mr. F. E. WENTWORTH-SHEILDS, M.Inst.C.E., in the Chair.

The following gentleman was submitted for election and was duly elected by the votes of the Meeting :—

MEMBER.

MR. ARCHER DAVE KEIGWIN, A.M.Inst.C.E. (by Examination) and Miller Prizeman, A.K.C. (London), Resident Engineer's Office, Kowloon, Hong Kong.

THE PRESIDENT announced the following elections by the Council :—

STUDENTS.

MR. JOHN EDMONDSON, M.R.San.I., A.I.S.E., Morecambe.

MR. JOHN TURNER MORRIS, London.

MR. FRANCIS WILLIAM PRESTON, B.Sc. Eng. (London), of Leicester.

THE PRESIDENT then presented the Annual Report of the Council together with the statement of Accounts.

REPORT OF COUNCIL FOR 1917-18 SESSION.

The present Membership of the Concrete Institute and its alteration since the previous figures were given for the 1916-17 Session are shewn in the following table :—

NUMBER OF MEMBERS.

	End of April, 1916.	End of Sept., 1917.	End of April, 1918.
Members	877	835	824
Associate Members ...	46	65	75
Associates	7	8	13
Students	57	57	56
Special Subscribers ...	5	4	4
Hon. Members	10	9	9
Total Membership ...	1,002	978	981

Of this total 369 reside in London and its environs, 324 reside in the provinces, and 288 abroad.

The apparent static condition of strength is to be accounted for by two facts: (1) Resignations and deaths resulting from the war, and (2) a careful weeding out of those who did not discharge their financial obligations to the Institute, and shewed no adequate cause for the neglect; as a matter of fact, there is a good infusion of new blood into the ranks of the Institute. Very many members are serving with the Forces either at home or abroad.

The finances of the Institute are shewn in the accompanying Balance Sheet. In 1913, 1914 and 1915 there was a deficit, and it must once again be noted that more subscriptions are in arrear than in normal times. A Sub-Committee of the Finance and General Purposes Committee was appointed to deal with these arrears; as a result some of these arrears have been made good. Judicious economy has again been exercised, but it was considered desirable to issue some of the "Transactions," more particularly in the interests of those who cannot attend the meetings. Consequently Volumes 6 and 8 have been taken in hand this Session, an intermediate volume being held in abeyance for the time being. By the recent issue of Volume 8, the Papers read in the Session 1916-17 have been made available, the printing of the Discussions on these Papers being held over for the time. The indulgence of the Members is once again asked for regarding any delay which the present war conditions render unavoidable, and it is confidently hoped and expected that after peace is declared and business again becomes normal, the past progress of the Institute will be fully maintained.

The following is a list of meetings held during the Session :—

1917.

Thursday, November 22nd.—Eighth Annual General Meeting. Seventy-fifth Ordinary General Meeting.
Paper by Dr. J. Newton Friend, D.Sc., on "The Corrosion of Iron and Steel, with special reference to Reinforced Concrete."

Thursday, December 20th.—Seventy-sixth Ordinary General Meeting, and Joint Meeting with the British Fire Prevention Committee.
"The effects of fire on Reinforced Concrete buildings as demonstrated by some recent examples," by Mr. H. Kempton Dyson and Mr. Ellis Marsland.

1918.

Thursday, January 24th.—Seventy-seventh Ordinary General Meeting.
Paper by Mr. E. A. W. Phillips, M.Inst.C.E., on "British Trade and the Metric System."

Thursday, February 28th.—Seventy-eighth Ordinary General Meeting.
Paper by Mr. Charles F. Marsh, M.Inst.C.E., etc., on "Criticisms of the London County Council's Regulations relating to Reinforced Concrete."

Thursday, March 21st.—Seventy-ninth Ordinary General Meeting.
Paper by Mr. H. L. Barraclough, on "Some practical points in the design and construction of Partitions."

Thursday, April 25th.—Eightieth Ordinary General Meeting.
Paper by Mr. H. J. Deane, M.Inst.C.E., etc., on "The Charterhouse Street Cold Stores of the Port of London Authority."

Thursday, May 9th.—Ninth Annual General Meeting. Eighty-first Ordinary General Meeting.
Paper by Mr. A. Alban H. Scott, V.-P.S.A., on "Reinforced Concrete Ships."

The thanks of the Institute are due, and are hereby tendered to the authors of papers; the meetings were only moderately well attended, but this is the direct result of the existing abnormal conditions.

As the result of a ballot among Members of Council, the

bronze medal for the best paper read in 1916-17 Session was awarded to Mr. Robert N. Sinclair, for his Paper entitled "Southampton Docks; re-modelling of an old Dry-Dock."

The Research on Concrete Aggregates which is being carried out under the direction of the Institute has made decided advance in 1917 in spite of the great difficulty in obtaining qualified research assistants, and seven provincial laboratories, viz., Birmingham University, Bradford Technical College, University College Cork, University College Dublin, Edinburgh University, Manchester Municipal School of Technology and Salford Royal Technical Institute have commenced work by collecting aggregates on which to carry out experiments. Four of them, Birmingham, Cork, Dublin and Salford, have made concrete specimens with these aggregates, and some of these have been tested. The Institute has to thank several firms who have supplied cement for this research, and also Messrs. Butler and Stanger, who have kindly carried out tests upon it.

The Institute, through its Science Committee, has at every meeting carefully considered points arising under the scheme, and on January 4th of this year a Joint Meeting of the Science Committee and those engaged and interested in the Research was held at the Institute, many useful matters being carefully threshed out. It was decided that a useful development of the movement might take the form of a list of aggregates throughout the United Kingdom, with their distribution, nature, properties, quantities available and prices quotable, together with further supplementary information. Arrangements have been made to obtain these particulars from various authorities. Full details of the Research Scheme and its results will be eventually reported to the Institute at large.

The Conference which was convened by the District Surveyors' Association to consider the interpretation of the London County Council (General Powers) Act of 1909 with reference to Steel-frame buildings, and on which the Institute is represented, held regular meetings during 1917, and has now presented its Report, which is awaiting printing and publication.

A Sub-Committee was appointed during 1917 by the Science Committee to consider the question of the use of High Tension Steels in Reinforced Concrete work, the reference being "to formulate a scheme for testing High Tension Steels for submission to the British Standards Com-

mittee." The following were appointed to serve on this Sub-Committee :—Mr. J. F. Butler, Mr. R. H. H. Stanger, Mr. B. Taylor, Mr. R. W. Vawdrey, and Mr. T. A. Watson. Mr. H. Kempton Dyson, in his capacity of Honorary Secretary *pro tem.* to the Institute, was also asked to serve on this Sub-Committee, and at its first meeting held on December 13th, 1917, he was elected Chairman and Honorary Secretary by unanimous vote. Invitations to act on the Committee were subsequently extended to representatives of certain firms interested in the question, resulting in the further appointment of Mr. H. R. White as representative of the United States Steel Products Company.

The Committees appointed by the Council for the Session were as follows :—

THE FINANCE AND GENERAL PURPOSES COMMITTEE.

Chairman—Mr. Charles F. Marsh.

Vice-Chairman—Mr. H. J. Tingle.

Ordinary Members—Professor Henry Adams, Mr. E. Fiander Etchells, Major J. E. Franck, Mr. H. D. Searles-Wood, Sir Henry Tanner, Mr. E. P. Wells, Mr. G. C. Workman, Mr. M. E. Yeatman.

Ex-officio—The President, and the Chairmen of Standing Committees.

THE SCIENCE STANDING COMMITTEE.

Chairman—Dr. J. S. Owens.

Vice-Chairman—Mr. H. K. G. Bamber.

Hon. Secretary—Mr. Ewart S. Andrews.

Hon. Secretary Research Committee—Dr. Oscar Faber.

Ordinary Members—Professor Henry Adams, Professor T. Hudson Beare, Mr. D. B. Butler, Colonel J. D. Cormack, Mr. E. Fiander Etchells, Major J. E. Franck, Mr. H. C. Johnson, Mr. Charles F. Marsh, Mr. W. G. Perkins, Mr. A. R. Sage, Mr. H. D. Searles-Wood, Mr. R. H. Harry Stanger, Mr. R. W. Vawdrey, Mr. E. P. Wells, Mr. F. E. Wentworth-Sheilds, Mr. M. E. Yeatman.

THE REINFORCED CONCRETE PRACTICE STANDING COMMITTEE.

Chairman—Mr. G. C. Workman.

Vice-Chairman and Hon. Secretary—Mr. R. W. Vawdrey.

Ordinary Members—Professor Henry Adams, Mr. Ewart S. Andrews, Mr. H. K. G. Bamber, Mr. P. J. Black, Mr. D. B. Butler, Dr. Oscar Faber, Major J. Petrie, Mr. F.

Purton, Major Lewis H. Rugg, Mr. A. R. Sage, Mr. A. Alban H. Scott, Mr. Archibald Scott, Mr. H. D. Searles-Wood, Mr. T. B. Shore, Mr. B. Taylor, Mr. J. M. Theobald, Mr. T. A. Watson, Mr. E. P. Wells, Mr. M. E. Yeatman.
Ex-officio—Mr. F. E. Wentworth-Sheilds.

THE PARLIAMENTARY STANDING COMMITTEE.

Chairman— Major J. E. Franck.
Vice-Chairman—Mr. Osborn C. Hills.
Hon. Secretary—Mr. Percy J. Black.
Ordinary Members—Professor Henry Adams, Mr. W. E. A. Brown, Mr. E. Fiander Etchells, Mr. W. G. Perkins, Mr. E. O. Sachs, Mr. L. Serraillier, Mr. E. P. Wells.
Ex-officio—Mr. F. E. Wentworth-Sheilds.

The Members of Council chosen to retire under the rules of the Institute were as follows :—Mr. Osborn C. Hills, Major H. Rogers, and Major Lewis H. Rugg, who were not eligible for re-election.

The Council nominated the following :—H. Kempton Dyson, F. Purton, A. Alban H. Scott, T. B. Shore, H. J. Tingle, R. W. Vawdrey. The results of the election will not be known in time for presentation in this Report.

The Council regrets to record the decease of :—

Killed in Action: Mr. F. L. Rings.
Died of Wounds: Lieutenant-Colonel B. S. Phillpotts, D.S.O., R.E.
Died: W. J. R. Barker, H.M. Office of Works; C. C. Keep (October, 1917); W. H. Martin (April, 1917).

One of our members, Captain Stanley C. Carter, R.E., has been awarded the Military Cross.

Several donations to the Library have been received from authors, publishers, and from kindred Societies, and the Council expresses its thanks to the various donors. A list of books received will be published in the Transactions.

FINANCE AND GENERAL PURPOSES COMMITTEE.

The Finance and General Purposes Committee have held regular meetings preliminary to each Council Meeting, and the general results of its deliberations are contained in the foregoing particulars of the Council's work for the year.

INCOME AND EXPENDITURE ACCOUNT.

Dr. Year Ending December 31, 1917. **Cr.**

INCOME.	£	s.	d.
To Annual Subscriptions	793	18	8
,, Special Subscriptions	31	10	0
,, Students' Subscriptions	11	11	0
,, Entrance Fees	31	10	0
,, Various Receipts	4	10	7
	£873	0	3
,, Balance brought down, being excess of Income over Expenditure, 12 months to date, as per Balance Sheet	95	0	4

EXPENDITURE.	£	s.	d.
By Office Salaries	291	0	0
,, Office Rent, Hire of Hall, Cleaning, Lighting, Heating	136	14	3
,, Printing, Reporting, etc.	245	2	8
,, Postages, Telegrams, etc.	27	17	9
,, General Expenses	35	14	6
,, Accountancy	8	8	0
,, Stationery	21	2	9
,, Amount written off Furniture for Depreciation	12	0	0
,, Balance carried down	95	0	4
	£873	0	3

RESEARCH GRANT ACCOUNT.

1917.		£	s.	d.
Dec. 31.	To amount of Grant received from Authorities for Research Work ...	830	0	0
	,, Interest on Deposit	3	13	8
		£833	13	8
	,, Balance brought down, being amount unexpended at date, as per Balance Sheet	723	5	8

RESEARCH GRANT ACCOUNT.

1917.					£	s.	d.
Dec. 31.	By Expenditure to date—						
	Aston Construction Co.	35	4	6			
	Univ. Coll., Cork ...	25	0	0			
	Dublin University ...	43	19	0			
	H. C. Johnson... ...	6	4	6			
					110	8	0
	By Balance carried down				723	5	8
					£833	13	8

BALANCE SHEET.

Year Ending December 31, 1917.

Dr. *Cr.*

LIABILITIES.				£	s.	d.
To Current Liabilities				184	1	10
,, Life Members' Subscriptions...				42	0	0
,, Surplus—						
Excess of Income over Expenditure, 12 months to date, as per Account	95	0	4			
Less—						
Excess of Expenditure over Income at 31st December, 1916, as per Balance Sheet at that date	52	14	1			
				42	6	3
				268	8	1
,, Research Grant—						
Unexpended Balance as per Account				723	5	8
				£991	13	9

ASSETS.				£	s.	d.	£	s.	d.
By Furniture—									
As at December 31, 1916 ...				114	0	0			
Less Depreciation ...				12	0	0			
							102	0	0
,, Cash—									
At Bank				156	7	3			
Petty Cash and Stamps ...				10	0	10			
							166	8	1
							268	8	1
,, Cash—Research Account—									
At Bank—Deposit				700	0	0			
At Bank—Current				23	5	8			
							723	5	8
							£991	13	9

We report to the Members that we have obtained all the information and explanations we have required, and that we have examined the above Balance Sheet dated 31st December, 1917, with the Books and Vouchers of the Concrete Institute. We certify that such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institute's affairs according to the best of our information and the explanations given us, and as shown by such Books and Accounts.

(Signed) MONKHOUSE, STONEHAM & CO.,
Chartered Accountants,
SALISBURY HOUSE,
LONDON, E.C.
19th March, 1918.

FOR THE CONCRETE INSTITUTE—
(Signed) F. E. WENTWORTH-SHEILDS, *President.*
C. F. MARSH, *Chairman of Finance Committee.*
PERCY L. MARKS, *Secretary.*

Science Standing Committee.

The work of this Committee during the past year has chiefly been concerned with the details of the Research Scheme above referred to. In addition the Committee have considered the suggested amendment of the London Building Acts and Building Bylaws generally, and it is hoped that something will be done in the matter in conjunction with other Societies. The Committee have also advised the Engineering Standards Committee at the request of the latter in respect to the use of special steels for reinforced concrete.

Reinforced Concrete Practice Standing Committee.

The Committee have completed the Report entitled "Recommendations to Inspectors, Clerks of Works and Foremen concerning the execution of Reinforced Concrete work." They have now taken in hand the consideration of the very important matter of the use of Reinforced Concrete as a substitute in articles hitherto made of timber. In this connection a fairly comprehensive list of such articles has been drawn up and is being submitted to a large list of firms, who are being invited to state which of these articles they are prepared both to design and make. Eventually the information obtained will be embodied in tabulated form, and will be placed at the disposal of the Board of Trade.

The Parliamentary Standing Committee.

The Committee have not held any meetings during the year under review.

Speaking on the Report, THE PRESIDENT said that he was sure that the members would agree that the Report was a very satisfactory one. The membership had only fallen off very slightly, and considering the war circumstances, that must be regarded as a very satisfactory feature. A great many new members had joined and the Institute could be said to be very much alive. In the matter of finance a feature was the strict economy that had been practised by the Council, for an adverse balance sheet last year of £52 had been turned into a credit balance of £42. There had been a number of interesting papers, all of which had excited a great deal of discussion. The Report also gave some particulars of the research work that was being carried on by the Institute under a grant from the Department of Scientific Research. They had seven laboratories at work belonging to various colleges and universities, and of these, four, viz.,

Birmingham, Cork, Dublin and Salford, had already made and tested concrete specimens in connection with the research. The President added that the Institute was organising a questionnaire, which it was hoped would bring together a great deal of useful information about these aggregates so that it would be possible for anyone to find out where they were to be obtained in the United Kingdom. The Report also stated that the Steel Frame Joint Committee, which had been formed by the Concrete Institute, the R.I.B.A. and the District Surveyors' Association, had completed their first Report and it was now ready for printing. It also mentioned that they were getting out a list of articles in which reinforced concrete could be usefully substituted for timber in order to meet the difficulty of the timber shortage.

The Report was adopted.

The result of the ballot for Members of Council was as follows :—Messrs. H. Kempton Dyson, F. Purton, A. Alban H. Scott, H. J. Tingle and R. W. Vawdrey.

Messrs. Monkhouse, Stoneham and Co. were re-appointed auditors.

THE PRESIDENT said that the next business should have been the presentation of the medal awarded in 1916-17 to Mr. R. N. Sinclair for his paper entitled "Southampton Docks : Re-modelling an old Dry Dock." They would be sorry to hear that Mr. Sinclair was unable to be present as he was engaged on urgent war work.

THE PRESIDENT said his next duty was to instal the new President, Mr. H. D. Searles-Wood. It was a great satisfaction to all that Mr. Searles-Wood had been elected. Although everyone knew his name and his long connection with the Institute, there were few, except those who had worked on the Council, who knew how much time and work he had given to their interests. He was a man who had worked exceedingly hard for the Institute, of which he was very proud, and he was one who would assuredly carry on its good work and preserve its traditions.

Mr. H. D. Searles-Wood, F.R.I.B.A., then took the Chair, and proposed a hearty vote of thanks to the retiring President.

Mr. F. E. Wentworth-Sheilds briefly thanked the members for the vote.

The following paper was then read :—

THE CONCRETE INSTITUTE :

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, Etc.

Date of Reading: May 9th, 1918.

Reinforced Concrete Ships.

By A. ALBAN H. SCOTT,

V.P. Society of Architects.

Four years ago reinforced concrete was hardly known, and certainly not understood, by many people outside the comparatively few architects and engineers who had studied and practised in this material.

During the period of the war its value and adaptability for a large variety of purposes have often been demonstrated, and at last a serious trial is being given to it for the construction of boats, which, if at all encouraging in results, will open up an almost illimitable field for the future.

The author does not propose to enter into a detailed history of the origin and uses of reinforced concrete, but wishes at first to be permitted to state a few particulars as to the Concrete Institute. This Institution was formed in 1908, the author being fortunate enough in being one of its Founding Members. Although the Institute is only 10 years old, it has 980 members, and is one of the real, live Institutes, always willing to learn and always willing to help all those who desire to take advantage of the results of its labours. The work done by the Institute on the L.C.C. Regulations in their draft form and since, ought to be of

considerable assistance in the study of ship construction in reinforced concrete.

Portland cement, the most important ingredient of concrete, is no new material to the steel shipbuilder, as it has for a long time been used as a substitute for paint or as a paving which protects the plating from attrition and corrosion. In certain parts of a steel ship, where oil paint would be difficult to apply, cement wash has been used for a number of years, and some useful information can be obtained from the steel ships as to the effect of foul bilge water; also the effect of long-continued wearing action of a stray bolt and in other ways. The uses to which Portland cement and concrete have been put in steel ships and the functions performed by such material are simple compared with those involved in reinforced concrete ships, and the rich proportions used up to the present time have probably had some influence in deciding upon rich mixtures for the reinforced concrete ships. Concrete intended for reinforced work, however, serves a purpose so entirely dissimilar that the former proportions have no relation to the proportions used for the reinforced concrete work.

The steel shipbuilder looks upon reinforced concrete as a very complex matter, chiefly owing to the large number of small rods and the overlap required to get continuity, but in comparing the form of jointing in reinforced concrete work to the riveting in steel ships and the caulking required one would perhaps be justified in thinking that it might be impossible to get a comparatively water-tight ship with steel plates, when it is considered that for a ship to, say, 1,000 tons D.W. for the hull alone there would be approximately 2,500 separate sheets and angles of steel used and somewhere in the neighbourhood of 110,000 rivets.

The approximate number of bars in a R.C. vessel (same D.W.) would be 52,000.

In the 1,795th issue of "Fairplay" the question is frequently raised as to what was meant by reinforced concrete ships. The author does not agree with part of the reply given, which is as follows:—

"Ferro-concrete, or, as it is otherwise known, reinforced concrete, is concrete in which the strength has been increased by the adding of steel, the amount of steel being reduced to the minimum which is essential to sustain those

stresses that the concrete is not capable of withstanding; the steel can only, however, be considered in most cases as a component reinforcing the whole structure. So far the reinforcements used in ferro-concrete ships consist of small bars, generally circular, but of such small sectional area as to bear practically no comparison to the shape of sections used in the members of the structure of a steel ship. Individually, these bars have little stiffness, but when they are held to the work they have to perform by the concrete in which they are embedded they become an important element reinforcing the whole structure."

The author rather describes it that "reinforced concrete" is a name given to a composite material where steel rods of comparatively small diameters are introduced into concrete to take up the whole of the tension stresses, to assist with the compression stresses and to take up part of the shear stress, the concrete not only acting as a protecting covering to the steelwork, but also taking up a good deal of compression stress and part of the shear stress, but in no case calculated to take any tensional stress. By this method of construction it is possible to introduce the steel where required, thus effecting a great economy in the use of steel; further, for ship construction the bars should be so placed and woven together that the whole of the skeleton steelwork of a reinforced concrete vessel should be rigid, each bar being held in position, and the steelwork treated rather in the nature of woven basket work than as loose and detachable rods.

At the same time this should not be construed into expressing agreement with the form of construction of certain boats under the name of "reinforced concrete boats," which have been or are being constructed, wherein the steelwork consists of sectional members as distinct from the small, round rods, such sectional members being held together by riveting and welding. It would seem that the objections to boats constructed in this method are the same as to land structures on such lines; in fact, it would appear to be almost going back to the same method of construction, as was previously adopted in buildings, by using sectional members and simply protecting them with concrete, without consideration of the functions exercised by each material in the distribution of stress.

As in all new forms of construction, a large number of

suggestions are being put forward for the combination of reinforced concrete with other materials.

Serious proposals have been put forward, of which the following are typical :—

> The bottom and upper decks being constructed in reinforced concrete with connecting frames of the same material, but the sides of the hull formed of steel or wood or a combination of these materials.
>
> For constructing certain portions of the vessels with unit parts by applying slabs of concrete (as plates of steel are applied), at the same time endeavouring to obtain manolithic construction.
>
> To form a laminated hull laid with steel reinforcing.

These various alternative methods of construction can only be evaluated by long periods of test under service conditions. It is suggested that the method of applying the concrete in the form of a plaster or by the method of depositing it in very thin layers will *not* be continued for a lengthy period.

Mr. Campbell Holmes stated in his book that the quality of cement is not often tested in the shipyard, and " it is not unlikely that where small quantities are indirectly supplied much of it may be inherently bad, which may not be discovered for years afterwards."

The testing of materials for reinforced concrete ships is one of extreme importance, and the Concrete Institute's report on this subject should be carefully studied. The whole of this report is applicable to shipwork, except that the maximum size of the coarse material requires, in the opinion of the author, to be reduced to $\frac{3}{8}$in.

Additional tests are desirable as to the impermeability of concrete, and also as resistance to shock.

Although a large amount of experimenting and testing on reinforced concrete has been carried out, much remains unknown when compared with ascertained data from research work undertaken on other materials, but no doubt, now that the shipping world is taking a practical interest, the money and opportunity will be found to conduct research work on proper lines, to add to our knowledge of the nature and properties of steel and concrete combined, as well as for concrete as a separate material. After these results have been obtained it will be time to consider more seriously the

question of reducing the weights of reinforced concrete hulls. Until additional research is undertaken, however, it seems to be inviting disaster, to use a very thin concrete of very rich mixtures without more knowledge of the true properties of one of the most important materials we are dealing with.

The necessity for checking the strength of the concrete immediately after placing in position is so important, that probably the artificial seasoning of concrete specimens by steam under pressure will have to be resorted to in ship construction, as by this means any weakness can be more quickly discovered. Much work remains to be done, before this accelerated "ageing" test can be considered to afford standardised data for guidance.

If we turn to the London County Council Regulations for reinforced concrete work relating to land structures, the safe permissible load as laid down by that body on the concrete can be ascertained for the various mixtures. It would appear that the tendency regarding ship construction is to increase the proportion of cement in the concrete for the purpose of obtaining additional strength and thus reducing the amount of concrete required. There is, comparatively speaking, little known on the question of concrete with its ordinary mixture equivalent to about 3-5-10, but there is less reliable information on concretes of very rich mixtures, except it is well established that the expansion and contraction, with consequent liability to hair-cracks, are much more pronounced in the richer mixtures than in the mixture mentioned above.

Entirely new conditions occur when dealing with steel embedded in concrete of a very rich mixture, and at this early stage it would seem a mistake to develop too quickly on to the concrete with a larger proportion of cement, and another point entering into consideration at this stage is the minimum thickness of concrete permitted, so that it will perform the various functions, it is called upon to undertake. If we take slab work with only one-mesh reinforcement the concrete has to be of sufficient thickness to act as a column in compression and to hold the steelwork in its true position under bending. The author would consider a $\frac{3}{4}$in. covering over all bars to be desirable, and, assuming a slab was made up with a mesh of $\frac{3}{8}$in. dia. bars running both ways, this would give the required thickness of $2\frac{1}{4}$ins., and, assuming the meshes were interlaced in the form of basket

work, it would give a thickness of 2⅝ins. Immediately we develop into double meshwork the minimum thickness would work out to about 4ins.

Apart from the question of the least thickness required to cover the bars from the points of view of proper adhesion and for general stability, the author thinks the minimum thicknesses should be 3½ins. for slabwork and 4ins. for beams and framings. Working with this thin construction, it is essential that all concrete, where it changes from one direction to another (such as a beam to a slab), and all internal and external angles, should be filleted, and if economically possible, rounded.

It is found in testing concrete, that the least satisfactory construction occurs at the internal angles, and it is actually at these points where a good deal of condensation takes place; and on the bottom, next the beams, a good deal of water accumulates, forming a catch-pit and position for corrosion.

The impermeability of concrete is of the greatest importance, and what may be gained on this point by using the richer mixture might be all sacrificed owing to the hair-cracks referred to elsewhere; therefore, rather than use at the present stage a rich mixture to obtain the results desired as to impermeability, it would be better for the moment to devote some attention to obtaining a material which could be applied to the surface of the concrete in the form of a wash of specially prepared tar or other bituminous material; if a coat of this description be properly applied, impermeability for many years should be secured. Even if the whole of the external surface of the vessel is not treated in this way, it would certainly be advisable to treat that portion, subjected to weather and tide.

In the construction of reinforced concrete, whether for land or water use, it might be borne in mind that this is one of the few constructional materials which cannot be properly and fully inspected after the completion of the work. In constructional steelwork it is possible to inspect, after the structure is complete, practically the whole workmanship on the job, but with reinforced concrete it is only possible to inspect the surface of the work after completion, and the structure after all depends upon the individual labour. Careful and intense personal supervision is therefore essential to ensure, first, that your steel is placed and maintained in

correct position during the progress of concreting; secondly, that your concrete is properly mixed; and thirdly, that it is properly punned and rammed into position.

When this point was raised recently at a meeting at this Institute the reader of the paper at that meeting stated "he could not see why, because a man was going to put in bad work, they must tell him he must design the structure far too strong for the job." Such a contention postulates the eventual elimination of the factor of safety, for which reason, above all others, it must be regarded as unsound. Supervision should be sufficiently vigorous, to ensure that the whole of the concrete is equally mixed and that the punning and ramming are efficiently executed; even under the best conditions concrete may vary very considerably in composition and strength, and for this reason it is necessary in the design of ship construction and in land structures in reinforced concrete that a greater factor of safety should be allowed than is usually advocated. If failure takes place of a land structure, a thorough investigation of the cause is generally possible, but in the case of failure of a reinforced concrete ship there will undoubtedly be a much greater difficulty in making full investigation, as the vessel will probably be resting on the bottom of the sea instead of floating on the surface.

In several references to reinforced concrete ships one notices the phrase that "concrete is poured in," and in the opinion of the author the loose application of this term should be combated. To obtain the best results, concrete should be *placed* into position as dry as possible, and after the concrete has been so placed, and sprinkled with water the result is a material much stronger and much more waterproof than a wet, sloppy mixture, or even a mixture which might be termed plastic; for this reason one would much sooner adopt the method of elevating the practically dry, mixed material in preference to delivery by gravitation.

In reinforced concrete one should not look upon the concrete work as a plastic material that can be poured, but rather as a dry material that has to be raised to efficiency by the admixture of water in small doses after the dry material is in its final position.

The condition in which the concrete is placed in the structure has some influence upon the most economical and the best method of laying out the plant for the construction

of the work, and in this connection we might for a moment consider in a general way the most convenient locality for the construction of the reinforced concrete vessels.

A good deal of discussion has been taking place as to the suitability of various sites for the construction of reinforced concrete vessels. It is necessary to consider first the materials involved. If we take a boat of, say, 1,000 tons D.W., we find we shall require approximately 40 tons of clean, fresh water, free from injurious foreign matter, 564 tons of aggregate, 234 tons of sand, 125 tons of cement, 160 tons of steel, and 138 tons of material for equipment in the way of machinery, etc. It is clear, therefore, that the combined weight of the sand and aggregate is 66 per cent. of the total required, including equipment. It would consequently appear desirable, so as to save the cost of freightage and the difficulties of transport, that waterways for these shipyards should be looked for in the neighbourhood of suitable stone quarries, where crushing plants could be put down and trolley-ways or rope-ways for transporting the material from the quarry to the shipyard could be arranged. It is also possible that cement could be obtained in the immediate district. If concrete in a relatively plastic condition be finally chosen such a method of transport from the quarries to the vessel obviously suggests that the material should be lifted above the ships, and after being mixed at a convenient level the concrete should be transferred by gravity to each particular vessel and part of the vessel requiring concrete at the moment. This method, however, the author suggests, requires too great a percentage of water.

If the drier mixture of concrete is used, the concrete should be partly mixed on a low level and elevated to the positions required.

The external centreing for reinforced concrete vessels will eventually be made movable in fairly large sections, and the plant lay-out for the concrete should be arranged in conjunction with the plant, necessary for easily removing the external centreing, by overhead gearing or by rails on the ground level, so as to take it clear of the boat while she is being launched, after which the centreing can be run into position again, ready for the next standard boat to be constructed. The internal centreing would be moved by overhead gearing and stored in a convenient position, also ready for the next boat. We have, up to the present

moment, gained little experience as to whether end-launching or broadside launching is most adaptable for vessels constructed of reinforced concrete. It might even be necessary to construct these boats in a dry dock if their size comes approximately to 5,000 or 6,000 tons D.W. The objection as a rule to using dry docks for the purpose of construction is the comparatively small output of tonnage in relation to the capital expenditure on the dock, but the speed of constructing reinforced concrete vessels at a properly laid out yard for standard designs might justify the expense of a dry dock, in view of the reduction of the cost and the minimising of risks involved in the floating of these vessels.

With this new form of construction for vessels the temptation to depart from true ship lines must be resisted. For many years investigations have been carried on to ascertain the lines, which give the least resistance to a ship passing through water; and because a different material is proposed to be used for certain boats it is submitted a great mistake would be made by departing from proper and regulated lines of the ship in the expectation of securing economies in construction in reinforced concrete. Safety and efficiency in running must be the first considerations. To depart from proper ship lines would involve extra expenditure on the running costs, which would quickly neutralise any saving on the capital outlay of the ship when constructed. No doubt it would be found that if five or six boats were built, with the same set of centering there would be no additional cost by having what is known as "circular circular work." It has been stated that it is more difficult to get the reinforcement into position by following the true ship lines than if straight lines are adopted. The obvious reply to this is, that it is more difficult to construct upper storeys to a building than lower storeys, therefore we won't have any upper storeys, or if it is more difficult to provide for hatchways, leave them out.

It will be found that the centering for the outside of the boats can be in large units, but for the interior of the boat the units will have to be comparatively small, as it is necessary that the concrete should not be "poured" from a great height. This will allow the centering on one side to be built up as the concrete is placed in position, so that efficient ramming and punning is ensured. Wherever possible concrete should be proceeded with as one complete operation, thus requiring day and night work with careful

organisation. The steel work should be as far as possible completed with the outside centering to one side of the internal beams and frames placed in position, before the concreting is commenced. With judicious arrangement of the internal strutting this can be achieved, and where it is necessary for the concrete operation to be temporarily suspended special care is required and special precaution rods must be inserted at such junction. It has not been found advisable to use neat cement grouting at these joints in the concrete.

The importance of testing each individual material used in reinforced concrete cannot be too strongly emphasised.

The following results of tests might be of interest :- -

By kind permission of the publishers the following extracts are given from " Reinforced Concrete in Practice."*

" It is important that ' flour ' should be eliminated from the sand. The actual size of the grains of sand in the concrete has a material effect on the strength of the work. Table No. 15 indicates the amount of surface to be covered by the cement."

Materials passing through a mesh of the following diameters.		Approximate total surface area of the particles contained in each cubic foot of material.
	Inches.	Square inches.
Sand.	0.0066 \ Should not be used for	1,530,000
	0.013 / R.C. work.	792,000
	0.025	412,000
	0.04	268,000
	0.06	194,000
	0.13	98,000
	0.25	45,000
Aggregate	0.37	28,000
or coarse	0.5	21,000
material.	0.62	16,000
	0.75	13,600

These areas are taken on the assumption that the grains have smooth and even surfaces, and no allowance has been made for irregularities of any description; they should therefore be considered as the minimum area.

* " Reinforced Concrete in Practice," by A. Alban H. Scott.

The amount of voids in the aggregate and sand when mixed renders it necessary to exercise the greatest care in grading the material. To ensure good compact concrete the voids should be reduced to the lowest percentage compatible with the elimination of "flour." The following table is the average of three determinations :—

	Percentage of voids.
Passing $\frac{3}{4}$in. and retained on $\frac{5}{8}$in.	48.2
$\frac{3}{8}$in. to $\frac{1}{2}$in.	44.5
$\frac{1}{2}$in. to $\frac{3}{8}$in.	43.4
$\frac{3}{8}$in. to $\frac{1}{4}$in.	42.9
$\frac{1}{4}$in. to $\frac{1}{8}$in.	39.8
$\frac{1}{8}$in. to $\frac{1}{16}$in.	39.0
$\frac{1}{16}$in. to $\frac{1}{32}$in.	35.5
$\frac{1}{32}$in. to $\frac{1}{50}$in.	34.5
Pit sand all passing $\frac{1}{4}$in. and retained on $\frac{1}{50}$in.	30.2 to 23.3
Broken granite passing $\frac{3}{8}$in. and retained on $\frac{1}{4}$in.	47.6 32.3
10 parts broken granite, all passing $\frac{3}{4}$in. and retained on $\frac{1}{4}$in., and 5 parts Leighton Buzzard sand, all passing $\frac{1}{4}$in.	22.6

The importance of cleansing aggregate and sand is illustrated by the following results :—

Description.	Clayey Deposit Precipitated on Washing.	
	Based on Gross Vol.	Based on Net Vol.
	Per cent.	Per cent.
Sample No. 1	14.5	20.4
,, No. 2	18.4	25.6
,, No. 3	9.8	13.3
,, No. 4	22.0	29.7
,, No. 5	5.3	7.0

The relative strength of concrete of varying proportions, composition, and age is indicated in the following particulars :—

	Lbs. per square inch.	
	Age 7 days.	Age 28 days.
Tensile strength of mortar.		
3 parts standard sand, 1 part cement	229.6	323.8
3 parts pit sand graded to standard and 1 part cement	204.4	280.6
3 parts ground brick, 1 part cement	109.0	146.0
Cement used had tensile strength of	460.8	552.0
Resistance to thrusting.		
3 parts standard sand, 1 part cement	1,628	2,050
3 parts pit sand, 1 part cement ...	1,143	2,021
3 parts ground brick, 1 part cement	955	1,355
	2 [illegible]	90 days.
Tensile strength of concrete (3-5-10)	146	205.7
Resistance to thrusting (3-5-10) ...	1,800	2,605
Shearing strength (ends not fixed) Cement and sand (3-1) ...	276	287
Ditto, but concrete (3-5-10)	308	343
Ditto, but cement and sand (ends fixed)	373	394
Ditto, but concrete	400	540

Result of tests to ascertain the resistance to thrusting of 6in. cube of concrete, average of 3 tests each. Proportions :—

10 parts Leicestershire granite.
5 parts Leighton Buzzard sand.
3 parts of cement (90lbs. as 1 cubic ft.).

All specimens taken from actual work.

Lbs. per square inch.

	7 days.	28 days.	90 days.	6 months.	9 months.
Series 1	1,373	2,750	2,437	2,560	3,319
,, 2	1,429	2,919	3,140	3,185	3,173
,, 3	1,243	2,087	2,779	2,971	—
,, 4	1,776	2,467	3,636	—	—
,, 5	759	1,600	1,935	—	—

Laboratory-made test cubes on same material.

		lbs.	lbs.		
Average	—	1,800	2,605	—	—

The following from specimens taken from work. Proportions as before, but pit gravel and sand graded and washed :—

Series 1	586	1,462	1,891	2,270	2,372
,, 2	654	1,188	1,444	2,063	2,161
,, 3	993	2,162	1,507	2,781	2,641
,, 4	733	782	1,238	2,209	1,419

Laboratory-made test cubes on same material.

	7 days.	28 days.	90 days.	6 months.	9 months.
Series 1	700	1,336	2,090	—	2,254
,, 2	1,153	2,167	2,684	2,927	3,100
,, 3	1,532	2,545	2,431	—	—

It is found that the weight of concrete varies considerably, according to the kind of aggregate and proportions used, but for all practical purposes for land work it can be taken at 148lbs. per cubic foot, but for ship construction

it should be taken at 156lbs., to which should be added the weight of the reinforcement in each case.

The concrete for such thin constructions as used in reinforced concrete vessels, if properly executed and with aggregate not exceeding $\frac{3}{8}$in., the weight per cubic ft. will be found to average about the weight given above.

It is not proposed in this paper to deal at length with the question of standardising for reinforced concrete ship construction, as the author feels, that those used to reinforced concrete require no convincing on this matter, and those who are used to steel ship construction are referred to a paper recently given by Sir George Carter, K.B.E., at the Institute of Naval Architects, where practically all his arguments in favour of standardised steel cargo boats apply equally to reinforced concrete boats. One advantage he mentions is so applicable to reinforced concrete boats that it calls for quotation here:—

"All the steel scantlings, after being settled in the ordinary manner, can be carefully examined to reduce the number of steel sections in the ship as much as possible. This results in producing the fewest changes of rolls at the steelwork and in the rolling of much larger parcels of materials to the one pattern on account of the large number of ships that are to be built to this design.

"As an example of this, in the standard ships now built the number of sections are reduced to 8 or 10, as against 30 to 40 used in pre-war days for the same type of ship."

In the reinforced concrete boats it would probably be possible to confine the diameters of the steel rods to six sections only.

Every bar, no matter what its diameter and no matter what its function may be, should have hooked ends, the hook being equivalent in radius to not less than five times the bar diameter; these hooked ends should not, under any circumstances, take the place of the necessary overlap required to get continuity of the bars, but should be an additional precaution to such overlap. Fish tailing or split ends of bars should not be allowed.

The usual method of welding steel bars should not be resorted to with steel intended for reinforced concrete structures for land or water use; the only satisfactory welding is the electrical welding, executed with proper plant and proper machinery. This should *not* be carried out on the actual job.

The proper connection and continuity of rods will have very material relation to the effect of vibration and shock on reinforced concrete work.

Experience with reinforced concrete, subjected to any vibrational shock in land structures has almost exclusively been confined to intermediate vibration—that is, heavy cranes in factories and in certain parts of railway work.

In shipping construction, however, the vibration may be considered continuous, and the effect of such continuous vibration on the adhesion of concrete and steel has not yet been ascertained; it can only be arrived at after a good many years of actual service. It is suggested, that a good deal of the vibration, caused by the engines and other machinery can be considerably reduced by the introduction of special anti-vibration foundation work, suitable for the plant, which will be installed in a ship, where one meets with the bases considerably less in size than is the case with plant of the same power in land structures. Such foundation beds would also tend to prevent the cracking of the concrete and cement work round about the machine beds. It has been proved that where travelling crane rails are put direct on to the reinforced concrete beams with only a steel plate for bedding there is a good deal of cracking away of the concrete after a period of five or six years' intermittent use, but where wooden sleepers have been introduced no such cracking away or loss of adhesion has been noticed; therefore it would appear desirable, in view of lack of knowledge on this point, that the effect of vibration in a reinforced concrete boat should be reduced as much as possible by tackling the problem at the machine beds and doing everything possible to reduce or to take up the vibration before it can attack the actual structure; possibly special packings for propeller shafts, as well as machine beds, would prove very beneficial in this respect.

It is not probable that concrete would be disintegrated by the continual vibration, but the adhesion of metal to concrete certainly might be affected, and it should be remembered that whereas some degree of plastic deformation may be expected in steel under stress, concrete, even if elastic, is certainly not plastic in the same sense as steel. There are but few real data as to the effect of shock loads on reinforced concrete; the tests carried out in Italy some years ago are interesting studies in this connection.

In all probability the Izod impact testing will be found exceedingly useful for gaining further information as to the

effect of shock loads on concrete of varying proportions and materials. Whilst dealing with the effect of shock on reinforced concrete, the question of the fire resistance of concrete should be considered. The claim that reinforced concrete is *fireproof* is quite erroneous. It is *fire-resisting*, and the effect of fire on reinforced concrete is not developed so quickly as it is on steel, and undoubtedly it will carry considerable loads without deformity whilst at a high temperature, which steel will not do.

With such a thin protecting coat of concrete, as we get in reinforced concrete boat work, it is necessary, both from a structural and fire-resisting standpoint, to have the steelwork well tied in, connected double-mesh work where possible, and extra care taken at all junctions; all arrises should be rounded or splayed. Properly designed and erected reinforced concrete work has undoubted claims over unprotected steel construction, and in arriving at the rate for insurance against fire the underwriters ought to take this into account; on the other hand, however, with grain cargoes any effect from swelling would have a more serious result on reinforced concrete than on steel, owing to the steel boat having greater elasticity. It must not be taken that reinforced concrete construction has every advantage and no disadvantages, but the efficiency as a whole must be considered.

What is the most efficient cargo ship? Assuming that the ship is seaworthy, the greatest economic value is obtained by a combination of the greatest registered tonnage, that can be carried and conveniently handled, and the cost of running at the required speed, together with the capital cost and the cost of upkeep.

The author is given to understand that most of the canal and dock dues are reckoned on the registered tonnage; therefore the reinforced concrete boat is not at a disadvantage on this particular point owing to its extra displacement. The cost of upkeep of a vessel depends so very much upon the uses to which it is put and the trade routes used, that it is difficult to get absolutely definite data for upkeep; but always assuming that the boats are seaworthy, reinforced concrete would in all cases cost very much less for upkeep than a steel or wooden boat. The comparative horse-power required for timber, steel, and concrete boats is given in a table elsewhere, which unfortunately shows considerably increased horse-power required for reinforced concrete for the same D.W.; but against this must be placed the lower

capital cost and the reduction in maintenance, and the point also must not be forgotten that there is big economy secured through the much greater speed in which concrete hulls can be built as compared with steel or wood hulls. This, of course, does not apply in the case where only one boat is constructed from one design; it is necessary in reinforced concrete boats for economy and speed that the designs should be standardised, but it must be, however, carefully guarded against that standardising does not mean stagnation, and a constant watch will have to be kept to see where the standard design can be improved upon from time to time and new standards adopted, so that the science will progress and not remain stationary.

To obtain correct comparative figures for boat work, it is desirable to take the D.W. capacity, and the author would like to take this opportunity of thanking Messrs. John J. Thornycroft & Co., Ltd., for kindly helping him with the following figures:—

COMPARATIVE FIGURES FOR WOOD, STEEL, AND REINFORCED CONCRETE SELF-PROPELLED VESSELS.

	R.C. design for 1,000 T.D.W. oil Engines or 950 tons steam.	R.C. design for 1,000 T.D.W.	Steel Ships for 1,000 T.D.W.	Wood Ships for 1,000 T.D.W.
Cost with machinery and all complete	25	26	37	44
Length B.P. ...	197′ 0″	200′ 0″	185′ 0″	187′ 0″
Breadth mld. ...	29′ 10″	30′ 6″	29′ 0″	29′ 6″
Depth mld. ...	18′ 3″	18′ 3″	14′ 0″	14′ 3″
Draft	15′ 0″	15′ 3″	12′ 10″	13′ 0″
Speed	9	9	9	9
I.H.P.	650	700	610	635
Weight of hull and outfit	912	957	430	520
Weight of machinery	138	143	120	125
Deadweight capacity	950	1,000	1,000	1,000
Displacement ...	2,000	2,100	1,550	1,645
Hull as percentage of displacement...	45·5	45·5	27.8	31.6
D.W.'s do. do. ...	47·5	47·5	64·5	60.7

These figures raise many general questions, and the author feels sure, we are only at the starting point of extraordinary developments for reinforced concrete work generally. Such development should proceed along careful lines, and if a special committee were appointed by this Institute, to consider the questions arising from time to time it would no doubt be exceedingly helpful.

In conclusion, he asks to be allowed to quote the first paragraph in the preface of a book referred to above:—

"Whilst the author is of opinion that there is no form of building so lasting, and requiring less maintenance than reinforced concrete, he considers it should only be employed when the work is under constant, careful, and experienced supervision, and when every material used in the work is tested."

There are some wonderful steel ships, there are also wonderful reinforced concrete buildings, and with the joint efforts of the naval and land architects there ought to be some wonderful reinforced concrete ships.

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DISCUSSION.

Mr. F. E. Wentworth-Sheilds, proposing a vote of thanks to the author, said he recollected how 15 or 20 years ago, when reinforced concrete first began to be talked of in connection with structures in this country, it was looked upon with very great suspicion. It had been found, however, that reinforced concrete was most useful and reliable, and that under water it behaved exceedingly well. But he thought there might be trouble with ships on the water line "between wind and water." It was a place where the naval architect had trouble with steel ships, and it was possible he might also have trouble with reinforced concrete ships. From experience of marine structures in reinforced concrete, however, he was inclined to think that a coating of good bituminous paint, as the author suggested, would give a long life to such ships.

Mr. S. W. Barnaby, Vice-President Inst. of Naval Architects, stated that he did not think that up to the present time any concrete ship had been subjected to stresses in a sea way, and it was that which they were most anxious about. Certainly concrete ships had come to stay for the period of the war, and concrete engineers were looked to for assistance in the proper way to calculate the strength of the midship section. Shipbuilders had been told that the concrete was only to be taken into account in its tensile strength. That meant that when they tried to get the neutral axis of a ship, assuming the ship to be on the crest of the wave and taking only the sectional area of steel in the deck and the sectional areas of steel and concrete at the bottom, the neutral axis would be very near the keel. The next minute when the ship was in the trough of the wave, if they took the sectional area of the steel only in the keel and of the steel and concrete in the deck, there was a great displacement of the neutral axis. It had been proposed, and he thought very reasonably, that special allowance should be made for this. Seeing that the steel only was to be counted as giving tensile strength in the deck in tension, the security of the bond became of the very first importance. If there was an overlap of about 40 diameters the grip of the concrete was equal to the strength of the steel, but if a ship was built in a hot climate and went into a cold climate, the grip might

be slightly reduced due to the contraction of the steel; and it was thought that the rods should be hooked as well as have a large overlap in order to give an additional security. Some builders were using rods roughly circular in section, but with three flattened sides, which they twisted. The advantage of that was that a better bond was obtained, and at the same time the elastic limit of the steel was raised. The author was wise in cautioning members not to expect the first concrete ship to be built more quickly than a steel one, although when once standardised methods were adopted, the process would be quicker. He did not look upon launching as a very difficult problem. The reason why stresses were put upon the ship in launching was this. The sliding ways were given an inclination of about $\frac{3}{4}$in. per foot, and in order to reduce the amount of woodwork for building up the ship, she also was built with an inclination of keel of about 9/16in. to the foot. If the ship was built without any inclination of keel, there would be no stress in launching, and in the discussion at the Institution of Naval Architects, it was suggested that the ships should be built with an even keel. In a 200ft. ship that would only mean that the keel would be 9ft. or 10ft. higher than with the ordinary inclination, which was a small matter. Any reduction between the 9/16in. inclination and even keel was all to the good in reducing stresses, and for that reason he did not see great difficulties in launching. He did not agree with building flat-sided or flat bottom ships because they required more horse-power to drive, although most of them built so far had been so constructed. If concrete engineers could secure the reinforcement sufficiently to prevent any displacement of it towards one side or other of the wall, then it would be much better to use a ship-shape form. One use to which ferro-concrete might be put was in providing additional bulkheads in existing ships, which at present had not a sufficient number.

Mr. H. K. G. Bamber, F.C.S., M.C.I., referring to a statement in the paper that the concrete should be placed into position as dry as possible and sprinkled with water afterwards, suggested the possibility of the result being an irregular stratified wall more dense in some places than others, especially with this form of construction in which the space between the shuttering was not more than about 4in. wide, and that partially filled by the reinforcement. The method did not appeal to him as one which would result in a homogeneous structure.

Dr. J. S. Owens, B.A., V.-P.C.I., said one valuable feature about the concrete ship was the ease with which it could be repaired compared with a steel ship, and that was important during the war. With regard to the factor of safety, we should remember that the factor of safety was a confession of ignorance on the part of the engineer, who made accurate calculations but did not know all the conditions and so multiplied his dimensions by four or six for safety.

Mr. H. J. Deane, B.E. (Sydney), A.M.Inst.C.E., M.C.I., said he did not think sufficient was known at the present time as to the requirements for insuring impermeability in concrete, and there was room for a good deal of work on the part of the Institute in this direction. Quite a considerable amount of information was available on the hydration of cement, mostly from Germany and America, and it would be a good thing if the Institute could collect such information from our own sources. His own experience was that the porosity of concrete decreased with age almost in a parabolic curve until it reached a point where it remained practically constant. He had some experience in connection with the waterproofing of a large concrete tank where trouble was anticipated. The tank was rendered inside with two coats of cement, and when sufficiently set the whole surface was kept constantly wet. After three or four weeks it was found that there was not a "drummy" patch anywhere, nor was there a hair crack to be seen. The surface treated was approximately 500ft. by 80ft. He was inclined to think that the construction of large reinforced concrete ships on launching ways would be the most economical method, as the allocation of a large dry dock for this purpose would involve on the Thames a hire charge of about £20 per day. There were several instances down the Thames where barges up to 1,000 tons were about to be built on low lying land behind the river walls. When the barge was ready for service the area was to be flooded and the barges floated out. This method might also commend itself for building concrete ships.

Mr. Francis R. Wade, Assoc.M.I.Mech.E., thought the suggestion as to the effect of vibration on rods was a most important factor in construction. It had been suggested in one of the letters that had been read that the trouble might be got over by adopting the turbine in place of the reciprocating engine; but the turbine had a vibration

which was just as insidious in its effect upon reinforced concrete construction as the reciprocating engine. This vibration would be a serious factor in the life of these ships.

Dr. Oscar Faber, D.Sc., M.C.I., said that in one of the papers read before the Institution of Naval Architects, it was stated that the life of the concrete ship was likely to be over a hundred years. The author of that paper then looked into the matter carefully and said that perhaps 50 years would be the most we could be absolutely certain of at present. He (Dr. Faber) did not wish to throw cold water on this question of the life of concrete ships, but he did not think they would last anything like 50 years. If they lasted 10 years he would think they had done very well. At the present moment, if the life was only three years, such ships would be well worth constructing; but at the same time he did not think we were at the moment justified in saying that the concrete ship would last longer than the steel ship. The concrete ship weighed 50 per cent. more than the corresponding steel ship, and if, after the war, steel was reasonably plentiful again, that increase in weight would handicap the concrete ship because that extra weight would have to be driven through the water and required more power to do it. He sympathised with the author's argument in favour of using a less rich concrete and relying more on paint, since it was very important to avoid shrinkage cracks. Mr. Deane's suggestion of keeping the concrete wet would go a long way towards this. There were good arguments for doing as the author had suggested, using a relatively poor concrete and relying on some form of paint for watertightness, but he was not satisfied that it was going to be a success. His experience was that practically no paint soaked into concrete to any great extent, and there was always the danger of it peeling off or being scraped off and causing trouble in that way. Another thing in connection with paint was that cement in its early days had a nasty habit of throwing off salts, and it was a well-known practice among builders not to paint any concrete wall for twelve months, because they find the paint does not stand. In the case of a ship, the only time it could be painted was before launching, when the cement was new, and he was afraid there would be serious difficulty. Therefore he was not quite satisfied as to how far it was possible to rely upon paint for effective waterproofing. He would like to know if the author had made any experiments on skin friction, which was an important

subject. He himself was making some experiments of this nature in conjunction with the National Physical Laboratory, and when they were completed the results would be available for anybody who desired to make use of them. If the skin friction in the case of the concrete ship was 30 per cent. higher than in the case of steel, as there was good reason to anticipate was the case, it would be a serious detriment to the concrete ship. Further, did the author adopt the practice of rendering his ships? With regard to classification rules, the Norwegian Veritas had issued some rules which, in his opinion, erred very much on the side of safety. They only allowed 5 tons per square inch on the steel in tension, and in addition they insisted upon longitudinal sections being designed for bending moments, which were often 50 per cent. or more greater than the bending moments, which calculations indicated were obtained. This had the effect of bringing the tensile stress down to $3\frac{1}{2}$ tons, which we all considered very low. Discussing some details of construction he (Dr. Faber) mentioned that the usual system was to work from a high scaffolding, to start lining up the centreing and to fix it from the scaffolding; but when it was remembered that the ship was curved in all sorts of directions it became a tremendous feat of carpentry to construct the moulds and to fix them sufficiently accurately in this manner without incurring excessive expenditure on rigid scaffolding

Mr. Scott, replying to the discussion, thanked Mr. Barnaby for kindly coming from Southampton for this discussion. So far as the proposed Committee was concerned, as far as he knew at present there was no Committee apart from the official Committee of the Admiralty. It was no use the concrete people discussing shipbuilding without the naval architects at their shoulders all the time, and the two ought to work closely together.

The security of the bond was a matter that was often discussed. His objection to the twisted bar was that nobody knew the effect of twisting on the steel. Even the mills did not seem to know what happened, and further, he did not think, in fact, that the deformed bar gave greater adhesion. Therefore until we knew exactly what happened to the twisted bar, he thought it best not to use it.

The suggestion by Mr. Barnaby to put in reinforced concrete bulkheads in existing ships was an excellent one, and he saw no reason why absolute watertightness should not be obtained between the concrete and the steel. Mr.

Bamber had not quite understood the method he had mentioned in the paper of making dry concrete. He was convinced that concrete, as dry as it could possibly be got, was the proper thing for getting watertightness and the greatest amount of strength. Mr. Deane had raised an interesting point about the hydration of cement, and so far as he could see, there was only about 70 per cent. of cement put into concrete, whether it was a wet or dry mixture, which actually fulfilled its functions.

The ease of repair to concrete ships of course depended on the nature of the damage. He did not agree with cement rendering of any class of work, subject to the conditions, that a concrete boat would experience, and if they were going to be a really commercial proposition, he thought it would pay to grind the surface on the outside in order to get an absolutely smooth surface. Grinding could be carried out in a very simple way and without the expenditure of a great deal of power. His suggestion of the use of a Dry dock for construction did not contemplate an expensive structure, and what Mr. Deane had suggested was being done down the river was exactly what he meant. As to the life of ships, he did not think they were called upon to give any opinion as to the number of years they would last. It depended entirely upon construction, but at the same time, unless Dr. Faber thought there was going to be action of the sea water on the cement, he did not know that he should necessarily limit it to 10 years.

Dr. FABER suggested there might be corrosion of the steel owing to the small cover of concrete.

Mr. SCOTT replied that, although a greater covering of concrete would increase the dead weight of the ship, it was better to do that to avoid corrosion, because to have only a covering of $\frac{1}{2}$in. or $\frac{3}{8}$in. in concrete was to ask for the death of the boats in three or four years. That was not the right form of construction, unless it was rendered necessary by emergency. Commercially a $\frac{3}{8}$in. covering was quite wrong, and it was not worth while discussing.

As to the centreing which had been mentioned by Dr. Faber, he did not propose to go into an argument as to his method of construction, but he would remind Dr. Faber that carpentry was not a lost art. The American boats shewed that it was possible to get ship lines with a reasonable degree of accuracy.

The meeting then closed.

The following communications were received :—

Mr. H. U. Sporborg, Chief Engineer, British Thomson-Houston Co., Ltd. : " When considering the question of stresses to which the hull of a concrete ship will be subjected, it must not be forgotten that the advent of the modern high speed turbine and either the electric or the double helical gear drive of the propeller make it possible to eliminate reciprocating parts from the propelling machinery of the cargo boat of the future. Such development means that the concrete ship need not be subjected to the pounding action of constantly repeated frequent shocks, which in time cause disintegration of concrete.

Judging from actual experience with reinforced crane gantries carrying heavy travelling cranes, which are provided with wooden sleepers under the crane rails, the use of wooden machine beds under heavy reciprocating pumps, etc., should eliminate any bad effects on the structure from machinery vibration.

There still remains, however, the one great uncertain factor of the effect on the hull structure as a whole of the twisting or torsional stresses of a heavy sea-way on the ship's quarter. Such stresses lie entirely within the purview of the naval architect and can best be met by actual experience, and the whole-hearted co-operation between naval and land architects and engineers which the author so eloquently urges."

Mr. Reg. J. N. Willcox, M.I.N.A., M.I.Mech.E., River Department, Port of London Authority : " Having had the pleasure of listening to Mr. Scott's paper and the interesting discussion thereon, I should like to offer some remarks which I hope may really prove helpful, although they do perhaps savour somewhat of destructive criticism.

The paper read by Gueritte before the N.E.C.I. of E. & S. and those read and discussed at the recent proceedings of the I.N.A. rendered great service to the progress of reinforced concrete vessels inasmuch as they brought us up against facts and put the whole subject upon a proper plane.

From the proceedings referred to it became evident that although the amount of steel in very small R.C. vessels might be but a small proportion of that in an all-steel vessel of the same dimensions (but of greater deadweight capacity), the proportion increased very rapidly with the dimensions.

In a recently constructed sea-going lighter, 150ft. long, 400 tons deadweight, it is about 30 per cent.

In a ship 205ft. long, 1,150 tons deadweight, Thornton states it is 42.5 per cent. of that in the all-steel ship.

In a 6,000 tons deadweight ship it will be of the order of 75 per cent.

A study of photographs of the larger sizes of vessels impresses one with the great quantity of steel bars and the complexity of their arrangement.

I think the author is on right lines in insisting on the retention of ship-shape form because of several reasons, not the least important of which is that abrupt change of contour introduces a sort of weakness which is particularly to be avoided in R.C. structures.

Assuming that ship-shape form will be adhered to in large vessels, certain primary problems in construction require very careful consideration.

When erecting all-steel ships the framing consisting of transverse and longitudinal components has to be secured in correct position under considerable constraint by ribbons, chocks and side shores. The addition of the skin and deck plating adds to the rigidity of the structure, but as weight is added, it is continually necessary to set up and readjust the supports in order to prevent sagging at the bilges and to maintain alignment, or as it is technically termed, 'to keep the hull fair.'

As far back as 25 years ago standardised ships were commonly built on the N.E. coast when the frames, etc., of several ships would be made off the same scrieves and moulds.

Notwithstanding this repetition and the care taken in the manner described, the differences in dimensions in detail are appreciable and, in fact, are reflected in slight variations in registered tonnage. In a very recent instance of the construction of one set of eight and another set of seven sister ships of special type, the same order of difference existed.

In the larger R.C. vessels we have much the same weight of steel to hold in correct position but in an infinitely less rigid structure. Because of the small cover, it is essential to hold it much more accurately in position or the bars will protrude through the surface of the concrete.

Assuming this has been satisfactorily accomplished and

concreting is begun, the work must go on continuously and an enormous weight of material be rapidly added to the structure.

In contrast to the all-steel ship, the added weight adds nothing to the rigidity of the structure, but must tend very sensibly to distort it and so force the reinforcing bars out of position.

Whether the shuttering can be made so absolutely rigid as to prevent distortion as weight is added, or whether means can be devised to adjust it and the reinforcement continually, experience alone can decide.

An impression exists that R.C. ships can be built much quicker than all-steel ships, but estimates given in the papers referred to put the time at four to six months. For correct comparison this must be put against the time an all-steel ship occupies a building slip, and it will be found that it exceeds it. Indeed, such ships can be ready for sea in this time.

Very great developments have already been made and are in progress which will simplify and expedite the construction of all-steel ships. The production of steel has also been enormously increased and is necessary.

With so small a saving of steel in large ships it is very doubtful that there will remain any inducement to consider R.C. ships of large size.

In large ships overstraining or plastic deformation is a common incident either as the result of working in a sea-way or of minor collision.

In very large ships "slip" joints have to be provided in the superstructures to avoid tearing asunder the steel. In vessels of medium size, local distortion and straining is frequent at the upper deck, at the forward parts of the bottom and at the bilges in certain parts.

A reinforced concrete structure is particularly unsuited to meet such conditions.

In large suction hopper dredgers the very rapid loading and discharging results in considerable deflection, and is reflected in intense local working of the structure which is taken up by the elasticity of the steel and its connections, and is the cause of considerable expenditure for repairs.

It is, I think, in the direction of small craft that the successful application of reinforced concrete is to be sought,

but unless it is employed only under proper conditions I fear that it may acquire an undeserved reputation as an unsatisfactory material for such craft. And this would have the effect of retarding progress in the proper application of reinforced concrete to floating structures.

Tugs and barges plying on the Thames and in London docks have to withstand most severe buffeting and abrasion, which result in extensive local deformations and fractures. For financial reasons it is not possible, nor is it necessary, to make repairs until the accumulated damage has begun to affect the integrity of the structure. This stage is often not reached before its battered and worn state has already appealed to the æsthetic senses and demanded restoration.

Such severe treatment would probably cause extensive cracking of the thin skin of a reinforced concrete tug or barge, which would result in unnoticed deterioration of the steelwork hidden in the concrete. When in this condition, unsuspected a slight bump may suffice to cause collapse of the side panels and probably total loss of cargo, which is often of great value.

The bottoms of barges and the keels of tugs are also subjected to much wear by reason of grounding and rubbing on gravel and stony bottoms or campsheds. It would seem that some form of protection which will not introduce severe local stresses will be called for here.

But where small craft have not to withstand these very severe conditions of operation there are very strong reasons for favouring R.C. construction, and its extensive and successful adoption may be safely predicted.

It appears to be pre-eminently suitable for small seagoing lighters, sailing barges, floating piers, pontoons, refuse barges, stationary suction dredgers, and those types of small craft which can be thoroughly protected by elastic timber fenders and are not likely to be subject to rough usage."

Mr. J. S. E. de Vesian, M.C.I.: "The author appears to consider that the rich mixtures being used to-day for ferro-concrete ships are the result of similar rich mixtures being used in steel vessels for protecting the bilges. I hardly think that this is the case, as, with few exceptions, the ships now being constructed are in the hands of firms used to ferro-concrete buildings and structures of all kinds, without any connection with shipping. Moreover, similar rich mixtures

have all been fairly common in sea works carried out in this country by the writer's firm during the last ten or twelve years.

The mixture mentioned by the author, namely, 3 : 5 : 10, concerning which he states there is little known, is after all analogous to the richer mixtures my firm have been in the habit of using in sea works, viz., 3.3 : 3.8 : 7.6, the results of which have been most satisfactory. No more tendency than with weaker mixtures has been noticed as regards hair cracking, but care is taken to insure the concrete being kept wet while setting, in which case there will be little fear of 'fine cracking.'

In several places in his paper the author appears to be very pessimistic about obtaining good concrete. In my opinion these fears are much exaggerated. Naturally, reinforced concrete work, with such small scantlings, has to be more carefully carried out than the rough and ready methods of the past with mass concrete, but it is not difficult to obtain a good result, and out of the thousands of ferro-concrete works carried out from my firm's designs, the number of cases where seriously inferior concrete has been met with are most reassuringly few.

The necessity for checking the strength of concrete by artificial seasoning immediately after placing in position does not seem to be very practical or necessary. The Admiralty specify that the concrete shall attain a crushing strength of 1,800lbs. at 7 days. It is not the strength of the concrete in ship construction so much as the provision of the proper cover to the reinforcement that decides the scantlings.

The suggestion put forward by the author that concrete should be placed in the moulds in a practically dry state and subsequently sprinkled with water, would in my opinion be unpractical as well as dangerous, because mixing in two operations would allow of the concrete being placed in the moulds after initial set had taken place and subsequently disturbed. This is a danger which has always to be carefully guarded against in practice and a constant watch kept upon setting times of cement to prevent its occurrence.

The author does not give his reasons for assuming the weight of concrete at 156lbs. per cubic foot for ship construction, but this would seem to be rather high.

On the question of vibration the author seems to doubt

whether there are any data available as to the behaviour of concrete under continual vibration, and especially as to the adhesion between the concrete and steel; but it should not be forgotten that any number of factories full of machinery (such as chocolate factories, spinning mills, printing works, which have unusually heavy vibrations) have been constructed of ferro-concrete and have been continuously in use for twenty years or more without the slightest trouble from this cause. There are also many travelling cranes running on concrete beams without any wooden packing between the rails and the concrete. Such a case was inspected a few days ago, where the beams had been in constant service for the last twelve years and no sign of trouble, such as lack of adhesion would shew, was apparent. With ordinary good workmanship no danger need be anticipated.

The author states that there are few real data as to the effect of shock loads on reinforced concrete, but what about the results of the tens of thousands of ferro-concrete piles which have been driven without shewing the slightest sign of injury? Also numerous accidental shocks such as that mentioned by Mr. W. Cleaver of Port Talbot, by Mr. C. S. Meik on the collisions with Purfleet Pier, and the numerous falling-weight tests carried out years ago on the Paris Exhibition buildings."

Mr. Walter Pollock, M.I.N.A., M.I.Mech.E., M.I.Mar.E., M.I. Metals (Messrs. James Pollock, Sons and Co., Ltd.): " I would like to propose that the great pioneer work as inaugurated by your Institute should be added to by the preparation of some rules to govern, or assist in, the design and construction of reinforced concrete vessels even with fairly wide limits. Further, I would like to propose that a Committee should be formed to make recommendations with a view of standardising many of the constructions and details, as it is painful to see the variety of designs that are at present being adopted.

Mr. Alban Scott raises the important question of ' straight lined ' versus ordinary ' ship-shaped ' vessels. It is probable that over one hundred reinforced concrete vessels are being constructed in this country at the present time with straight lines or straight frames, which I introduced in July, 1917, all of which are intended for a sea or river speed of not more than 7 to 8 knots. Mr. Scott has no doubt seen the published designs of several of these, and it would be interesting to know if he seriously

thinks that the shape will adversely affect the speed, the co-efficient of fineness being the same. I submit that at the speeds quoted or at any 'coastwise' speed, the difference will be infinitesimal. It will surely be admitted that the 'straight lined' vessel will be much cheaper to construct, will result in better construction for thin slab work and will expedite delivery. I believe at least two well-known members of your Institute, Mr. E. P. Wells and Dr. Oscar Faber, share my views, and no doubt several other members will express theirs.

Probably the percentage of steel reinforcement compared with that of a steel ship in the various constructions throughout the world shews a greater diversity of opinion than any other important part of the design. The working stress allowed on the mild steel varies 100 per cent. in the designs, and whilst the limits are so wide, useful comparisons of saving and economy cannot be given and this proves the necessity of some rules being adopted."

Mr. A. W. C. Shelf, M.C.I.: "I congratulate the author on his collection of data at such an early stage in this new and important branch of ship construction.

In his concluding remarks the author condemned the use of physically developed or twisted bars, and went so far as to say that no one (not even the suppliers or makers of twisted bars) knew what happened to the steel.

This is another instance of a little knowledge being a dangerous thing. Evidently the author has not read the paper given by Mr. Van der Broek at the Iron and Steel Institute on May 3rd this year, entitled 'Effect of cold working on the elastic properties of Steel,' or the paper given by myself before the Society of Engineers on March 5th, 1917, entitled 'High Tensile versus Mild Steel for Reinforced Concrete,' for which the Society awarded me the Bessemer Premium; otherwise I feel sure he would not have been so ready to condemn the use of bars which are now being employed in their tens of thousands of tons for reinforced concrete shipbuilding.

I challenge the author to prove that any injury is done to mild steel bars physically developed in a scientific manner. Doubtless the author has in mind the early failures that took place with twisted bars which had not been treated scientifically; but considerable progress has been made during the last eight years by those who have treated the physical

development of steel bars as a scientific study and not purely as a commercial concern, and I venture to say that the use of physically developed steel bars in reinforced concrete is of great economic importance, as they combine all that is essential for monolithic structures, having a high yield point both in tension and compression (which is the limit of resistance for reinforced concrete), a high buckling resistance (which should be taken into consideration in the question of modular ratio) and a slight continuous mechanical bond which the writer maintains is an extra safeguard in the event of failure of the adhesive bond (see page 136 of my paper referred to herein); and further (which is an important factor) they take an increasing load to cause the steel to yield further after the first yield point of the steel has been reached; whereas mild steel bars, besides having a very low yield point and buckling resistance, continue to extend under the same load after the first yield point has been reached.

Another important feature of physically developed bars is the fact that they are always free from mill scale, whereas mild steel bars often have the mill scale adhering to them when they are embedded in the concrete."

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NOTE.—Due to the need by printers of the speedy liberation of type, whilst the war was in progress, the Institute had its complete stock of the Sessional Papers printed straight off the machine. This renders continuous pagination throughout the Volume impossible. To make it possible to introduce an Index the following indicative lettering has been employed:—

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"B" ,, ,, Discussion on Prof. Adams' Paper on "Piles."
"C" ,, ,, ,, ,, Mr. C. R. Peers' Paper on "The care of ancient monuments."
"D" ,, ,, Eighth Annual and the Seventy-fifth Ordinary General Meetings, with Dr. J. Newton Friend's Paper on "The corrosion of iron and steel."
"E" ,, ,, Seventy-sixth Ordinary General Meeting.
"F" ,, ,, Seventy-seventh Ordinary General Meeting, with Mr. E. A. W. Phillips' Paper on "British trade and the Metric System."
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1909. DAVENPORT, John A., M.Sc., B.E., Assoc.M.Inst.C.E.; Baths Department, Municipal Buildings, LIVERPOOL, Lancashire.

1914. DAVEY, Herbert J.; 25 Dancroft Road, Herne Hill, LONDON, S.E.24.

1909. DAVIDSON, David, M.C., F.R.Soc.Arts; 31 Regents Park Terrace, Headingley, LEEDS, Yorkshire.

1909. DAVIDSON, John A., Lieutenant, R.E., Assoc.M.Inst.C.E.; 218 Great Western Road, ABERDEEN, Scotland.

1909. DAVIES, Charles Gilbert, M.S.A.; No. 10 The Bund, SHANGHAI, China.

1911. DAVIS, A. C., F.C.S., M.Inst.C.E.; British Portland Cement Manufacturers, Ltd., 4 Lloyd's Avenue, LONDON, E.C.3.

1911. DAVIS, F. W.; c/o The British Portland Cement Manufacturers, Ltd., Magheramorne Lime Works Branch, MAGHERAMORNE, via Belfast, Ireland.

1908. DAVIS, J. W.; Kenilworth Park Avenue, WITHERNSEA, E. Yorkshire.

1909. DAWSON, T. C.; 37 Cornwall Avenue, Bounds Green Road, Wood Green, LONDON, N.22.

1914. DAY, B. J., M.Inst.E.E., A.M.I.Mech.E.; 3 Park Place, CARDIFF, Wales.

1912. DAY, J. Percy; 3 Victoria Street, Westminster, LONDON, S.W.1.

1909. DEACON, Thomas Mark, F.S.I.; 32 Craven Street, Charing Cross, LONDON, W.C.2.

1908. DEANE, Henry H., M.Inst.C.E.; Arisail, SHANKHILL, Co. Dublin, Ireland.

1913. DEANE, Henry J., B.E.(Sydney), M.Inst.C.E.; Chief Assistant Engineer, Engineer's Office, Port of London Authority, 100 Leadenhall Street, LONDON, E.C.3.

ENROLLED.

1913. DEARLE William W., M.Q.S.A.; 13 John Street, Adelphi, LONDON, W.C.2.

1908. DELAP, Alfred D., M.Inst.C.E.; Northern Bank Chambers, 115 Grafton Street, DUBLIN, Ireland.

1909. DE PAULSEN, C. L. H., B.Sc., M.S.E., M.I.C.E.(Danish); c/o Messrs. Thomas Cook & Son, RANGOON, Burma, India.

1910. DE PEYRECAVE, Gaston R.

1908. DESCH, Henry Thomas; 93 Mount Pleasant Road, South Tottenham, LONDON, N.15.

F.C. DE VESIAN, J. S.E., M.I.Mech.E., M.S.E.; 38 Victoria Street, LONDON, S.W.1.

1913. DEWAR, John; Union Bank Chambers, 214-216 Bishopsgate, LONDON, E.C.2.

1909. DIBDIN, Lionel Aglio, M.I.Mun.E., M.I.San.E.; Avondale, Grosvenor Avenue, WALLINGTON, Surrey.

1908. DICKSEE, Sidney J.; Starborough House, RUGBY, Warwickshire.

1913. DICKSON, James; Cumberland House, ST. ALBANS, Herts.

1910. DICKSON, John, Assoc.M.Inst.C.E.; 48 Gray's Inn Road, LONDON, W.C.1.

1909. DIGGLE, James, Assoc.M.Inst.C.E.; Borough and Water Engineer, Town Hall, HYDE, Cheshire.

1919. DITCHBURN, David W., A.R.I.B.A.; Standard Building, Hornby Road, Fort, BOMBAY, India.

1908. DIXON, Stephen M. (Professor), M.Sc., M.A., M.Inst.C.E.; The Department of Civil Engineering, City and Guilds Engineering College, Exhibition Road, LONDON, S.W.7.

1909. DODD, Peter, M.Inst.C.E.; Borough Engineer of Wandsworth, 215 Balham High Road, LONDON, S.W.17.

1912. DONALDSON, David, M.Nat.Assn.Cement Users.

1909. DONE, J. J., F.S.I.; "Whitemead," HENDON, Middlesex, N.W.

1910. DORMAN, William S. H., B.A., Assoc.M.Inst.C.E.; Public Works Department, Secretariat, LAHORE, India.

1910. DORMOR, R. D., Captain, R.E.; Assoc.Inst.San.E.; Royal Engineers, GIBRALTAR.

1913. DOVASTON, John, A.R.I.B.A.; The Cottage, SLINDON COMMON, near Arundel, Sussex.

F. DREW, Alexander, M.I.Mech.E.; 15 Ashley Gardens, Westminster, LONDON, S.W.1.

1909. DRING, Francis; "Holmlea," Page Terrace, NORTON-ON-TEES, Durham.

1913. DRURY, F. E., F.I.S.E.; "Greenbank," 46 Moorfield Road, Pendleton, MANCHESTER, Lancashire.

F. DUFF, M. B., M.Inst.C.E.; 42 Frederick Street, EDINBURGH, Scotland.

1909. DUGUID, Alexander T., Assoc.M.Inst.C.E.; c/o Messrs. Grindlay & Co., CALCUTTA, India.

1912. DUNCAN, Charles A.; Public Works Department, Ramgarh, RANCHI, Behar and Orissa, India.

1913. DUNDAS, Kenneth; 93 West George Street, GLASGOW, Scotland.

1909. DUNN, P. Livingston, Assoc.M.Inst.C.E.; 715 Cole Street, SAN FRANCISCO, California, U.S.A.

F. DUNN, William, F.R.I.B.A.; 35 Lincoln's Inn Fields, LONDON, W.C.2.

ENROLLED.

1910. DURRANT, Frank, F.A.I.; "Staplake," Russell Hill, PURLEY, Surrey.
1917. DYSON, H. W. C. Kempton; 10 Old Burlington Street, LONC. DON, W.1.

1908. EASTERBROOK, F. J.
1909. EASTON, J. Dalgleish; Harbour and Dock Offices, LEITH, Scotland.
1913. EBDON, William, Assoc.M.Inst.C.E.; King George Dock, Hebdon Road, HULL, Yorkshire.
1918. EDWARDS, Alfred H.; 102 Oakwood Court, Kensington, LONDON, W.14.
1910. EDWARDS, A. O.
1910. EDWARDS, Gerald T., Assoc.M.Inst.C.E.; Water Works Office, Bowling Green Street, LEICESTER.
1910. EDWARDS, Kendrick; Scottish Temperance Buildings, BELFAST, Ireland.
1910. EDWARDS, L., M.J.I.E.; P.O. Box 1158 JOHANNESBURG, South Africa.
1912. EDWARDS, Spencer, P.A.S.I.; 205 Richmond Road, CARDIFF, Wales.
F. EGERTON, W., M.S.A.; 12 Queen's Road, ERITH, Kent.
1913. EILOART, R. E., Stud.R.I.B.A.; 17 Elsworthy Road, LONDON, N.W.3.
1911. ELIOT, M. E. Yorke, Major, Assoc.M.Inst.C.E.; Avenue House, St. John's Road, BOSCOMBE, Hampshire.
1908. ELLIOTT, E. C.; Circular Quay, SYDNEY, N.S.W.
1912. ELTON, P. Ion, A.R.I.B.A.; District Surveyor for Putney and Roehampton, 223 Upper Richmond Road, Putney, LONDON, S.W.15.
1909. ENGLAND, Arnold; Carlton Chambers, St. ANNE'S-ON-SEA.
1908. ETCHELLS, E. Fiander, Assoc.M.Inst.C.E., A.M.I.Mech.E.,
V.P.,C. Hon.A.R.I.B.A.; New County Hall, LONDON, S.E.1.
1908. ETHERIDGE, H. O. H.
1911. EVANS, Arthur E.; c/o E. Ringwood, Esq., 86 Bowes Road, PALMER'S GREEN, Middlesex, N.13.
1908. EVANS, Frank D., Assoc.M.Inst.C.E.; Public Works Department, KUALA LUMPUR, Selangor, F.M.S.
1918. EVANS, John G.; "Highbury," Harrop Road, HALE, Cheshire.

1911. FABER, Oscar, O.B.E., D.Sc.; c/o Messrs. Colls & Sons and
C. George Trollope & Sons, Ltd., 5 Coleman Street, LONDON, E.C.2.
1911. FARRELL, Chas., M.Auckland Valuers Assn.; Hobson Buildings, Shortland Street, AUCKLAND, New Zealand.
1908. FASEY, William R., F.Z.S.; Grove Green Yard, Leytonstone, LONDON, E.11.
1909. FENWICK, H. Eagleson.
1909. FERGUSON, William, M.A., B.A.I., M.Inst.C.E.; 131 Coromandel Street, WELLINGTON, New Zealand.
1912. FETT, William E. J.
1909. FFORDE, F. C., M.Inst.C.E.; Lindisfarne, BROADSTONE, Dorset.

ENROLLED.

1908. FILLAKY, A. A.; District Surveyor for Greenwich, Borough Hall, Royal Hill, Greenwich, LONDON, S.E.10.
1909. FIRR, T. F., Assoc.M.Inst.C.E.; Public Works Department, BOMBA, Nyasaland, South Africa.
1909. FISHER, W. D.
1908. FITZGERALD, Gerald, Assoc.M.Inst.C.E.; P.O. Box 461, WELLINGTON, N.Z.
1910. FLEMING, J. Gibson, Captain, R.E.; c/o Messrs. Cox & Co., 16 Charing Cross, LONDON, S.W.1.
1909. FLINT, F. Dean, Assoc.M.Inst.C.E.; c/o Messrs. Thos. Cook & Son, Post Box No. 78, RANGOON, Burma, India.
1919. FORD, Charles R., F.R.G.S., F.N.Z.I.A., M.S.A.; P.O. Box 294 WANGANUI, New Zealand.
1908. FORD, Lawton R., A.R.I.B.A., F.S.I.; District Surveyor for St. James's, Westminster, 60 Haymarket, LONDON, S.W.1.
1912. FORDER, H. C.; 7 Adelaide Road, BRENTFORD, Middlesex.
1913. FORSTER, W. B.; Detmold Chambers, 237 Collins Street, MELBOURNE, Australia.
1908. FOSTER, Frank, M.Inst.C.E., Estacion Once, F.C. Oeste, BUENOS AIRES, Argentine, S. America.
1909. FOWLER, Ernest G.; Architect and Surveyor to Educational Committee of Leicester County Council, Whetstone House, WHETSTONE, near Leicester.
1909. FOWLER, Richard S., Lieutenant, R.E., B.A., Assoc.M.Inst.C.E.; Ardbrae, BRAY, Co. Wicklow, Ireland.
1908. FOX, Senior F. L., Assoc.M.Inst.C.E.; Deputy Sewage Engineer of the Egyptian Government, CAIRO, Egypt.
1909. FRAME, D. B., F.N.Z.I.A.; P.O. Box 160, NAPIER, New Zealand.
1912. FRANCIS, L. P.; 21 Norman Road, THORNTON HEATH, Surrey.
F.C. FRANCK, J. Ernest, Major, F.R.I.B.A.; 1 New Court, Lincoln's Inn, LONDON, W.C.2.
1909. FRECH, S. Alfred, M.Inst.C.E.; Parliament Mansions, Victoria Street, LONDON, S.W.1.
1909. FRYER, Henry; Assistant Manager, Building Works Department, Royal Arsenal, Woolwich, LONDON, S.E.18.

1909. GADD, W. Laurence, Lieutenant-Colonel, Kent R.G.A., F.I.C.; 7 Lansdowne Square, ROSHERVILLE, Kent.
1909. GAFFNEY, Stafford, M.A.I.(Dublin), Assoc.M.Inst.C.E.; Monart, ENNISCORTHY, Co. Wexford, Ireland.
1909. GALBRAITH, A. R., M.Inst.C.E.(Ireland), F.S.E.; c/o Bank of Australasia, Martin Street, SYDNEY, N.S.W.
1908. GALBRAITH, J. P., Major, R.E.; c/o Messrs. Cox & Co., 16 Charing Cross, LONDON, S.W.1.
1911. GALBRAITH, William; Fareham, Dashwood Road, GRAVESEND, Kent.
1911. GAMMON, John Charles, B.Sc.(Eng.), A.C.G.I.; c/o Messrs. Wm. Jacks & Co., 5 Murzban Road, BOMBAY, India.
1908. GARDINER, James; 6 Blandford Square, Marylebone, LONDON, N.W.1.
F. GASCOIGNE, George H.; The General Fireproofing Co., 3 Central Buildings, Westminster, LONDON, S.W.1.

ENROLLED.

1914. GAYTON, H., A.M.O.S.A.; "Burlington," Kenilworth Road, The Polygon, SOUTHAMPTON, Hants. (To be forwarded.)
1908. GEEN, A. Burnard, Assoc.M.Inst.C.E.; 122 Victoria Street, Westminster, LONDON, S.W.1.
1900. GENDERS, P. R., P.S.A.I.; c/o Chief Surveyor, Land Titles Office, REGINA, Sask., Canada.
1913. GIBSON, George H.; Queensberry Arms Hotel, ANNAN, Scotland.
1917. GIBSON, George McL., Assoc.M.Inst.C.E., M.I.Mech.E.; Building Works Department, Royal Arsenal, Woolwich, LONDON, S.E.18.
1912. GIBSON, J. W., O.B.E.; The Hollies, Poplar Road, Linthorpe, MIDDLESBROUGH, Yorks.
1912. GILBERT, J. T.; 62 Bedford Road, HARROW, Middlesex.
1909. GILLESPIE, Peter, Assoc.M.Can.Soc.C.E.; c/o Librarian, University of Toronto, TORONTO, Canada.
1912. GILLIES, Robert; 13 Church Street, KINGSTON, Jamaica.
1909. GILRUTH, William, F.S.I.; H.M. Office of Works, National Provincial Bank Chambers, James Street, LIVERPOOL, Lancashire.
1910. GLASSON, A. H. W., A.R.I.B.A.; 5 Madrid Road, Barnes, LONDON, S.W.13.
1909. GLOVER, James, M.A.(Cantab.), M.Inst.C.E.; Lowton House, LOWTON, Lancashire.
1910. GOAD, C. E.; 53 New Broad Street, LONDON, E.C.2.
1909. GOLDING, H. H., A.R.I.B.A.; 12 Casewick Road, WEST NORWOOD, S.E.27.
1909. GOLLA, Lucian C.; Corso Cavallotti 34, SAN REMO, Italy.
1909. GOODWIN, John D., M.I.Mun.&C.E.; Borough Engineer, Town Hall, ASHFIELD, N.S.W., Australia.
1912. GOULDING, W. W., P.A.S.I.; 8 Marshall Road, Levenshulme, MANCHESTER, Lancashire.
1912. GRAHAM, Allan, A.R.I.B.A.; 15 Primrose Mansions, Battersea Park, LONDON, S.W.11.
1909. GRANT, J. G., Major, R.E.; Port Directorate, BASRA, Mesopotamia Expeditionary Force.
1912. GREEN, A. W., B.A., B.E.; Neangor, Tryon Road, Lindfield, SYDNEY, N.S.W., Australia.
1913 GREEN, W. A., M.A., B.Sc.,Eng.(St.Andrews), Assoc.M.Inst. C. C.E.; 3 King's Avenue, EALING, W.5.
1913. GREGORY, C. M.; Rushbrooke, MUSSOORIE, India.
1911. GREY, Geo. W., F.S.I.; 48 Cranbourn Street, LONDON, W.C.2.
1918. GRIEVE, Charles J. K., M.I.Mech.E., M.I.Mar.E.; Post Box No. 20, KUALA LUMPUR, Selangor, F.M.S.
1919. GRIFFITH, John; Building Works Department, Central Office, Royal Arsenal, Woolwich, LONDON, S.E.18.
1910. GRIGSON, T. Reginald, Assoc.M.Inst.C.E.; Engineer's Department, Belfast Harbour Board, BELFAST, Ireland.
1908. GRIMSHAW, Ernest F. W.; "Coleshill," West Mill, BUNTINGFORD, Hertfordshire.
1909. GROVER, Benjamin J.; Wilton Works, New North Road, Islington, LONDON, N.1.
1909. GULLEY, Frederick, E.
1913. GWYTHER, J. Richard, Captain, M.A.(Manchester).
1908. GYDE C. J.; Public Works Department, Union Buildings, PRETORIA, South Africa.

ENROLLED.

1909. HABGOOD, W.; c/o Messrs. C. P. Kinnell & Co., St. Julian's Avenue, St. Peter's Port, GUERNSEY, Channel Islands.

1908. HAHN, D. M., M.Inst.C.E.; Public Works Department, PORT OF SPAIN, Trinidad, W.I.

1909. HAIGH, William Henry, Assoc.M.Inst.C.E.; City Engineer's Department, City Hall, CARDIFF, Wales.

1908. HALL, A. A., B.A., B.E.(Royal), Assoc.M.Inst.C.E.; P.O. Box 261, ALEXANDRIA, Egypt.

1909. HALL, E. Lawrence; 1 Gresham Buildings, Basinghall Street, LONDON, E.C.2.

1919. HALL, Herbert G. R., Captain; Eaton Villa, Hopper Road, PALMERS GREEN, Middlesex, N.13.

1910. HALL, Lionel C., Captain, M.C., Assoc.M.Inst.C.E.; c/o The Secretary, Port Commissioners, Post Box No. 85, RANGOON, Burma, India.

1913. HALL, W. Carby, F.R.I.B.A.; Prudential Buildings, Park Row, LEEDS, Yorkshire.

1918. HALLIDAY, Thomas C.; P.O. Box 122, QUEENSTOWN, Cape Colony, S.A.

1915. HAMILTON, F. B.; 14 Broad Street, Marine Parade, BRIGHTON, Sussex.

1909. HAMILTON, F. W., A.R.I.B.A.; District Surveyor for Paddington, 195 Edgware Road, LONDON, W.2.

1909. HANCOCK, John Stanley; Box 1,920, JOHANNESBURG, Transvaal, South Africa.

1911. HANKINSON, Alfred; 107 Pitt Street, SYDNEY, Australia.

F. HANNEN, Benjamin, B.A.; 258 Gray's Inn Road, LONDON, W.C.1.

1911. HANSON, S. Charles, M.S.A., A.I San.E.; Beverley, SOUTHALL, Middlesex.

1913. HARCOURT, A. Percy, Assoc.M.Inst.C.E.; Morley Lodge, 16 Morley Road, Lewisham, LONDON, S.E.13.

1919. HARDING, Charles A., Lieutenant, R.N.V.R., A.R.I.B.A., Dipl.Archt.Glas.; 10 Springfield Road, WALLINGTON, Surrey.

1910. HARDY, E. C.

1909. HARLING, W.; Caixa Postal 4, SANTOS, Brazil.

1909. HARRIS, F. E. L., A.R.I.B.A.; 1 Balloon Street, MANCHESTER, Lancashire.

1908. HARRIS, Leopold J., A.M.I.E.E.; Royal Societies Club, 63 St. James's Street, LONDON, S.W.1.

1918. HARRISON, Leonard C., Captain; 30, Albert Palace Mansions, S.W.11.

1909. HART, Arthur J., Assoc.M.Inst.C.E.; Pendennis Chambers, 375 George Street, SYDNEY, N.S.W., Australia.

1909. HART, Gilbert; c/o London Joint City and Midland Bank, SOUTHAM, Warwickshire.

1909. HARVEY, H. S. S., A.K.C., Assoc.M.Inst.C.E.; King's Way, MIRANDA, N.S.W.

1913. HASKELL, J. V., M.I.Surv.N.Z.; Public Works Office, WELLINGTON, New Zealand.

1910. HASLAM, J. T.

1908. HASTINGS, Harold, Assoc.M.Inst.C.E.; Puerta del Angel 10, BARCELONA, Spain.

F. HASTINGS, Percy; Technical Journals, Ltd., 27 Tothill Street, Westminster, LONDON, S.W.1.

ENROLLED.

1911. HATTON, George, M.Iron&SteelInst.; Earl of Dudley's Round Oak Works, BRIERLEY HILL, Staffordshire.

1914. HATTORY, Seizo, M.Inst.C.E.(Japan Imperial); Chief Civil Engineer of Mitsui Mining Co., Ltd., Müke Colliery, Omuta, FUKUOKAKEN, Japan.

1912. HAUGHTON, Hubert.

1909. HAY, James Johnston; P.O., HITCHIN, Hertfordshire.

1908. HAYWARD, Arthur B., P.A.S.I.; 14 John Street, Adelphi, LONDON, W.C.2.

1909. HEALEY, A. J., A.R.I.B.A.; 36 Princess Road, Regent's Park, LONDON, N.W.1.

1909. HEATHCOTE, Edgar H., Major, M.A.(Cantab.), Assoc.M.Inst. C.E.; Lloyd's Bank Building, King Street, MANCHESTER, Lancashire.

1909. HEAZELL, A. Ernest; Burton Buildings, Parliament Street, NOTTINGHAM.

1909. HEBDON, William; 56 Tressillian Road, LONDON, S.E.4.

1909. HELLIWELL, Hubert; Engineer and Surveyor's Department, 18 Falkland Road, Egremont, WALLASEY, Cheshire.

1909. HERSCHEL, A. E. H.; 2314 Second Street West, CALGARY, Canada.

F. HEWINS, Henry; Waterworks Engineer, Town Hall Square, GRIMSBY, Lincolnshire.

1910. HIGGINS, John; 46 Alexander Street, GREYMOUTH, N.Z.

1909. HIGHAM, Hugh V.; Katchmass, near BAKU, South Russia. ("Xarmcab" to be written on left hand corner of envelope.)

1909. HILL, Edmond J.

1909. HILL, W. M.; "The Yews," 77 Beulah Hill, Upper Norwood, CROYDON, Surrey.

1908. HILLS, Osborn C., F.R.I.B.A.; District Surveyor for the Strand, 60 Haymarket, LONDON, S.W.1.

1909. HINCHSLIFF, Edward R., Assoc.M.Inst.C.E., F.S.I.; Deputy Town Surveyor, Public Offices, BARRY, South Wales.

1909. HINDES, E. J., A.R.San.I.; 24 Station Road, BECCLES, Suffolk.

1909. HINDSLEY, James; 25 Church Crescent, Muswell Hill, LONDON, N.10.

1913. HINGSTON, Frederic W., M.Q.S.A.; 9 Old Square, Lincoln's Inn, LONDON, W.C.2.

1913. HIRSCH, Ernest; c/o Kleine Fire Resisting Flooring Syndicate, 133-136 High Holborn, LONDON, W.C.1.

1909. HIRST, Joseph H., M.S.A.; City Architect, Town Hall, HULL, Yorkshire.

1914. HOGAN, J. F. G.; overseer, Karachi Buildings, P.W. Dept., HYDERABAD, Sind, India.

1908. HOLMAN-HUNT, H. L., C.I.E., Assoc.M.Inst.C.E.; Executive Engineer, Twante Canal, P.W.D., RANGOON, Burma, India.

1909. HOLME, George, M.Sc., Engineer; c/o Messrs. H. S. King & Co., 9 Pall Mall, LONDON, S.W.1.

1908. HOLT, William, Assoc.M.Inst.C.E.; Engineer and Surveyor to U.D.C., SALE, Cheshire.

1913. HOMAN, Edgar H.; 17 Gracechurch Street, LONDON, E.C.3.

1913. HONNOR, Timothy, F.R.I.B.A.; New Zealand Buildings, 79 and 81 Pitt Street, SYDNEY, N.S.W., Australia.

1909. HORSFORD, F. J.; Assistant Engineer of Works, Public Works Office, PORT OF SPAIN, Trinidad, West Indies.

ENROLLED.

1918. HOTHERSALL, Francis L., M.S.E.; 96 Manor Park, LEE, S.E.13.
1908. HOWARD, James; Engineer and Surveyor to Worsley U.D.C., Council Offices, WALKDEN, Lancashire.
1909. HOWARTH, Frank, M.Inst.C.E.; Water Engineer to Plymouth Corporation, Municipal Buildings, PLYMOUTH, Devon.
1908. HOWE, Thomas H., Lieutenant, A.S.A.M.; Rossmore, 25 Grosvenor Road, ILFORD, Essex.
1909. HOWELL, George T.
1909. HOWKINS, J. D., M.A.(Oxon.); Engineer to Hartlepool Port and Harbour Commission, Engineer's Office, HARTLEPOOL, Durham.
1909. HUBBACK, Theodore R., Assoc.M.Inst.C.E.; Pertang, JELEBU, F.M.S.
1909. HUDDART, Lindow H. L., M.A.(Cantab.), Assoc.R.S.M., Consulting and Mining Engineer; 2 and 3 West Street, Finsbury Circus, LONDON, E.C.2.
1910. HUDSON, E. H.; Acting District Engineer, N.G.S. Railway, JALUA (Deccan), India.
1910. HUGHES, A. C.; The Ingle, Park Road, WOKINGHAM, Berkshire.
1910. HUGHES, E. C.; Albion Works, WOKINGHAM, Berkshire.
1908. HUGHES, John, M.I.Mech.E.; 16 Victoria Street, LONDON, S.W.1.
1909. HUMMEL, Frank H., M.Sc.(Birmingham), Assoc.M.Inst.C.E.; The Queen's University of Belfast, Engineering Dept., BELFAST, Ireland.
1909. HUNTER, M. H., F.I.San.E.
1909. HUNTLEY, Alfred H.; 212 Melfort Road, THORNTON HEATH, Surrey.
1908. HURST, Bertram L., M.Inst.C.E., M.I.Mech.E.; Craig's Court
C. House, Charing Cross, LONDON, S.W.1.
1909. HUTTON, Samuel, M.R.San.I.; Town Surveyor and Water Engineer, Town Hall, EXMOUTH, Devon.
1910. HUXLEY, William Sheerin, M.S.A.; KUALA LUMPUR, Selangor, F.M.S.
1909. HYDE, Vere Sussex; 12 Highfield Road, DUDLEY, Worcestershire.

F. IANSON-ROBSON, W. L.; Emerson Chambers, Blackett Street, NEWCASTLE-ON-TYNE, Northumberland.
1912. IFE, Charles B.; 7 Kempe Road, Kensal Rise, Kilburn, LONDON, N.W.6.
1909. INAGAKI, Hyotaro, M.Inst.C.E.; Imperial Railway Construction Office, Chubu Tetsudo Kwanrikioku, Shiodome, Shiba, TOKYO, Japan.
F. INCHLEY, W. P.; c/o Messrs. Inchley & Co., Little Peter Street, Gaythorn, MANCHESTER, Lancashire.
1908. INGHAM, O. H.; 20 Broughton Road, SOUTH SHIELDS, Durham.
1908. INMAN, H.
1913. INMAN, Wm. C., P.A.S.I.; Ash Villa, North Street, HORNCHURCH, Essex.

ENROLLED.

1909. JACKAMAN, Charles James, Assoc.M.Inst.C.E.; "Highfield," Bath Road, SLOUGH, Buckinghamshire.

1909. JACKSON, J. E., Assoc.M.Inst.C.E.; Kuala Lipis, PAHANG, F.M.S.

1912. JAGGER, P. B.; The Improved Construction Co., Ltd., 47 Victoria Street, LONDON, S.W.1.

1913. JAMIESON, Francis A., Licentiate R.I.B.A.; 11 Podium Road, Stoneycroft, LIVERPOOL, Lancashire.

1912. JARDINE, James M.; Inspector of Works, 20 Firs Street, DUDLEY, Worcestershire.

1909. JERRAM, G., Assoc.M.Inst.C.E.; Engineer and Surveyor to Merton U.D.C., Council Offices, Kingston Road, MERTON, Surrey.

1909. JOBSON, C., M.Inst.C.E.; 29 Princess Buildings, St. George's Terrace, PERTH, Western Australia.

1909. JOHNS, J. Henry, M.Inst.C.E.; Thorsden, Guildford Road, WOKING, Surrey.

1918. JOHNSON, Arthur L., M.A.(Cantab.); c/o Messrs. Richard Johnson, Clapham & Morris, Lever Street, MANCHESTER, Lancashire.

1908. JOHNSON, E. T. Morland, M.I.Min.E.; Bank of England Chambers, MANCHESTER, Lancashire.

1913. JOHNSON, H. C.; 1 Park View, Victoria Road, CORK, Ireland.

1909. JOHNSON, H. J., F.S.I.; 21 Queen Anne's Gate, LONDON, S.W.1.

1908. JOHNSON, J. Healey, M.Inst.C.E.; Engineer to Witham General Commissioners and Witham Outfall Board, Witham Office, BOSTON, Lincolnshire.

1910. JOHNSTONE, John T., F.S.I., Licentiate R.I.B.A.; Hillside, BLETCHINGLEY, Surrey.

1909. JONES, J. Arthur, F.S.I.; H.M. Naval Depôt, DOVER, Kent.

1913. JONES, T. A.; 45 Lyndhurst Road, THORNTON HEATH, Surrey.

1909. JUDAH, Braham T., Assoc.M.Inst.C.E.; Assistant Engineer, Kingston General Commissioners, KINGSTON, Jamaica.

1909. KATTAN, Mustafa H. el; Egyptian State Railways, Engineer-in-Charge, New Alexandria Station, ALEXANDRIA, Egypt.

1908. KAYE, L. Lister; Manor House, Stretton, RUGBY, Warwickshire.

1909. KEENOR, Edward L., M.S.A.; Post Office, Box 6038 JOHANNESBURG, South Africa.

1908. KEEVILL, R. Graham, A.M.I.Mech.E.; 7 Palewell Park, East Sheen, LONDON, S.W.14.

1918. KEIGWIN, Archer D.; Resident Engineer's Office, Holt's Wharf, KOWLOON, Hong Kong, China.

1913. KELK, H. M.; c/o Messrs. Richard Johnson, Clapham & Morris, Ltd., 42 and 42a Broad Street House, New Broad Street, LONDON, E.C.2.

1909. KELLER, Peter, Engineer; Public Works, Bag No. 2, WHANGAMOMONA, New Zealand.

ENROLLED.

1913. KERNER-GREENWOOD, J. H.: St. Ann's House, KING'S LYNN, Norfolk.
1909. KERSEY, A. H., F.R.I.B.A.: 21 Finsbury Pavement, LONDON, E.C.2.
1912. KESSON, J. M.: 18 West Hill, HUDDERSFIELD, Yorkshire.
1908. KEY, T. D., Assoc.M.Inst.C.E.: Alexandria Water Company, ALEXANDRIA, Egypt.
1909. KIKKAWA, Sanjiro, M.E., Assoc.M.Inst.C.E.: 10 Nishikata-machi Hongo-Ku, TOKYO, Japan, via Siberia.
1912. KING, Charles A., Assoc.R.C.S.(Ireland), A.M.I.Mech.E.: Principal of Engineering College, Benares Hindu University, NAGUA, Benares, India.
1908. KING, William F.: 3 Vauxhall Bridge Road, LONDON, S.W.1.
1908. KINGWELL, A. E., M.S.A.: Beech Hill Park Estate, HADLEY WOOD, Middlesex: also 103 and 104 Cheapside, LONDON, E.C.2.
1909. KINLOCH, E. T.: 23 Oakfield Street, CARDIFF, S. Wales.
1910. KIRK, John W., F.S.I.: 30 Stockwell Road, LONDON, S.W.9.
1913. KNIGHT, Victor H.: c/o Concrete Seacraft, Ltd., 308 Royal Liver Building, LIVERPOOL, Lancashire.
1913. KNOTT, F.; Burnett Avenue, High Street, HULL, Yorkshire.
1918. KÖTASTHANE, Vinayakrao M., B.A., B.Sc.: Picket Road, 65-67 Kalbadevi, BOMBAY, India.

1909. LACY, R. H.: "Essendon," Hedge Lane, Palmer's Green, LONDON, N.13.
1908 LAKEMAN, Albert; 100 Kingsbury Road, Erdington, BIRMINGHAM, Warwickshire.
1911. LAL, P. Hira.
1913. LAMBOURNE, Alfred W.; The Hollies, 32 Sandford Road, Moseley, BIRMINGHAM, Warwickshire.
F. LANCASTER, H. P.; 104 Victoria Street, LONDON, S.W.1.
1914. LANE, Alfred, P.A.S.I.: 14 Natal Road, THORNTON HEATH, Surrey.
1919. LANGDON, Horace W.: Building Works Department, Royal Arsenal, Woolwich, LONDON, S.E.18.
1912. LASCELLES, W. H.: Parliament Mansions, Victoria Street, Westminster, LONDON, S.W.1.
1910. LAWSON, Henry W., Assoc.M.Inst.C.E.: Harbour Works, FORT HARCOURT, Southern Nigeria, Africa.
1909. LEACH, Claud Harry.
1913. LEAHY, William J., Licentiate R.I.B.A.: 22 Ullswater Road, Southgate, LONDON, N.14.
1913. LECKY, R. J.; Northern Bank Building, REGINA, Sask., Canada
1910. LEE, G. Allen, M.Am.Soc.E., A.M.I.Mech.E.: P.O. Box 138, NEW PLYMOUTH, Taranaki, N.Z.
1914. LEICESTER, William, M.S.A.; Lapley, Tennae Road, Harborne, BIRMINGHAM, Warwickshire.
1909. LEIGHTON, John M.: c/o Concrete Piling Co., Broadway Court, Westminster, LONDON, S.W.1.
1909. LEITCH, Archibald, M.I.Mech.E.; 49 Lonsdale Road, Barnes, LONDON, S.W.13.
F. LESLIE, P. W.; "Madgelands," Beaconsfield Road, Blackheath LONDON, S.E.3.

ENROLLED.

1912. LEVERTON, W. J. H., Licentiate R.I.B.A.; H.M. Office of Works, King Charles Street, Westminster, LONDON, S.W.1.
1912. LEWIS, Cecil T.; Ivy Bank, Stock, near INGATESTONE, Essex.
1909. LEWIS, D. Ivor, M.S.A., M.R.San.I.; P.O. Box 667, JOHANNESBURG, South Africa.
1913. LEWIS, H. M., M.R.San.I.; The Pollards, WOKINGHAM, Berks.
1913. LIMA, A. V. C.
1909. LISTER, Charles; 11 Athol Road, Alexandra Park, MANCHESTER, Lancashire.
1913. LITTLE, Andrew; 102, Norwood Road, STRETFORD, Lancs.
1908. LIVINGSTONE, Benjamin; 47 Victoria Street, LONDON, S.W.1.
1909. LLOYD, Richard, Assoc.M.Inst.C.E., M.I.Mech.E.; 11 Victoria Street, Westminster, LONDON, S.W.1.
1909. LOVEGROVE, E. J., M.Inst.C.E.; Borough Engineer and Surveyor for Hornsey, Municipal Offices, Southwood Lane, Highgate, LONDON, N.6.
1919. LOVEGROVE, Gilbert H., F.R.I.B.A.; 374 Old Street, LONDON, E.C.2
1912. LOVELL, A. Wadsworth; Chief Engineer's Office, Hull and Barnsley Railway, Charlotte Street, HULL, Yorkshire.
1909. LOWIS, F. C.; Executive Engineer, Public Works Department, RANGOON, Burma, India.
1909. LOWSON, James; 80 Guild Street, ABERDEEN, Scotland.
1909. LUCAS, William, A.R.I.B.A.; c/o J. S. Thompson, Esq., Torrens Street, College Park, ADELAIDE, S. Australia.
1908. LUKE, Alfred J.; 23 East Cliff, DOVER, Kent.
1909. LYALL, W., M.I.M.E.; 19 Victoria Road, DARLINGTON, Durham.
1913. LYDDON, A. J., Assoc.M.Inst.C.E., P.A.S.I.; Engineering Inspector's Office, St. William's College, College Street, YORK.
1919. LYNAM, Charles G. J., Major, R.E.; c/o Civil Commissioners, BAGDAD, Mesopotamia.
1909. LYON, L. E., B.Sc.; Assistant United States Engineer, U.S. Engineer's Office, NORFOLK, Virginia, U.S.A.
1912. LYTTLE, S. G., Assoc.M.Inst.C.E.; c/o Assistant Engineer, P.W.D., Karachi Buildings Sub-Division, KARACHI, Sind, India.

1908. McALPINE, T. Malcolm, Assoc.Inst.C.E.; 2 Central Buildings, Westminster, LONDON, S.W.1.
1919. McANDREW, George D., Major, R.E.; D.A.D.W., Civil, BASRAH, Mesopotamia.
1911. McAVEN, Joseph Stanley.
1910. McCADE-SMITH, F.; Resident Engineer, Elder Dempster Co., New Staff Quarters, CALABAR, S. Nigeria, West Africa; also "The Laurels," Greasby, BIRKENHEAD, Cheshire.
1908. McCLEAN, William N., M.A.(Cantab.), Assoc.M.Inst.C.E.; c/o Cocks, Biddulph & Co., 43 Charing Cross, LONDON, S.W.1.
1909. McCLURE, J., Assoc.M.Inst.C.E.; 45 Whitefriars Crescent, WESTCLIFF-ON-SEA, Essex.

ENROLLED.

1911. MACDERMOTT, A. T., Assoc.M.Inst.C.E., M.A., B.A.I.(Dublin); Junior Naval and Military Club, 96 Piccadilly, LONDON, W.1.

1914. McDONALD, C. Fleming; N.Z. Express Co.'s Buildings, Port Street, AUCKLAND, New Zealand.

1918. MACDONALD, James V.; M.I.Mech.E.; 15 Farringdon Avenue, LONDON, E.C.4.

1908. MACDONALD, M., Sir, K.C.M.G., M.Inst.C.E.; Director-General of Reservoirs, Reservoir ASWAN, Egypt.

1908. McDONALD, Thomas J., Assoc.M.Inst.C.E.; c/o Sir R. McAlpine & Sons, 27 Mosley Street, NEWCASTLE-ON-TYNE, Northumberland.

F. McDOWELL, T. J.; Empire Stone Co., 231 Thanet House, Strand, LONDON, W.C.2.

1908. McFARLANE, T.; 11a Myddleton Square, LONDON, E.C.1.

1909. McGLASHAN, John; District Engineer, Port Commissioners, CALCUTTA, India.

1908. McGREGOR, James, Assoc.M.Inst.C.E.; Canadian Government Railways, 137 Pleasant Street, HALIFAX, N.S.

1913. MACKAY, W. A.; 9 Tillotson Road, Cranbrook Park, ILFORD, Essex.

1909. MACKENZIE, A. C., M.Inst.C.E.; Engineer to Harbour Trust, MELBOURNE, Victoria, Australia.

1909. MACKINTOSH, L., M.I.Mun.&C.E.; City Engineer, Municipal Office, MANDALAY, Burma, India.

1912. MALCOLM, James A.; The Improved Construction Co., Ltd., 47 Victoria Street, LONDON, S.W.1.

1909. MAPLESDEN, C. W.; Assistant Director of Barrack Construction, 16 Albemarle Street, LONDON, W.1.

1918. MARCHMENT, Wallace, Licentiate R.I.B.A.; 41 Ovington Street, Cadogan Square, LONDON, S.W.3.

1908. MARKHAM, John H., A.R.I.B.A.; 82 Radnor Road, HARROW, Middlesex.

1909. MARRABLE, Francis F. T.; Clerk of Works, Royal Dockyard, Woolwich, LONDON, S.E.18.

F.C. V.-P. MARSH, Charles F., M.Inst.C.E.; Chief Assistant Engineer, Metropolitan Water Board, South Place, Finsbury, LONDON, E.C.2.

1913. MARSHALL, A. E.; 27 Nightingale Lane, Hornsey, LONDON, N.8.

1913. MARSHALL, John; Wickham Street, Arncliffe, SYDNEY, N.S.W., Australia.

1909. MARSHALL, John Scott, M.C., Assoc.M.Inst.C.E.

1913. MARSLAND, Ellis R., Captain; Court House, PAINSWICK, Gloucestershire.

1908. MARTIN, A. D. De R., Lieutenant, R.E.; c/o Messrs. Cox & Co., 16 Charing Cross, LONDON, S.W.1.

1909. MARTIN, R. E., C.M.G., M.A.(Cantab.), Assoc.M.Inst.C.E.; The Brand, near LOUGHBOROUGH, Leicestershire.

1909. MARTIN, V. J., M.Sc.(Victoria), Assoc.M.Inst.C.E.; Public Works Department, JELEBU, Negri Sembilan, F.M.S.

1912. MASON, J. Blair, M.Inst.C.E.; Consulting Engineer, P.O. Box 138, NEW PLYMOUTH, Taranaki, New Zealand.

1914. MATHIESEN, Julius, M.DanishInst.C.E.; The Tunnel Portland Cement Co., Ltd., WEST THURROCK, Essex.

ENROLLED.

F. MATTHEWS, Ernest R., Assoc.M.Inst.C.E.; Chadwick Professor of Municipal Engineering in the University of London, University College, Gower Street, LONDON, W.C.1.

1919. MATTOCKS, Frederick S., Lieutenant, R.E.; Garrison Engineer, Manora, KARACHI, India.

1908. MAWSON, George T.; "The Dunes," Marve, near Malad, B.B. & C.I. Railway, Thana District, SALSETTE, Bombay, India.

1913. MAXTED, G. V.; Burnett Avenue, High Street, HULL, Yorkshire.

1910. MEAD, Frederick W., M.Illum.Engrs.Soc.; 114 Forest Road, TORQUAY, Devon.

1909. MEARS, Robert P., B.A.(Cantab.), Assoc.M.Inst.C.E.; c/o Messrs. Cox & Co., Hornby Road, Fort, BOMBAY, India.

1909. MEDLEY, Lewis; c/o Messrs. W. Jacks & Co., 1 Lall Bazaar, CALCUTTA, India.

1908. MEIK, C. S., M.Inst.C.E.; 10 Victoria Street, LONDON, S.W.1.

1909. MERCER, Ernest G.; District Engineer, P.W.D. IBADAU, Western Province, Southern Nigeria, WEST AFRICA; and Briarside, Longlands Park Road, SIDCUP, Kent.

1912. MEREDITH, Edward, A.R.I.B.A.

1914. MESSY-RHINE, Laurell.

1913. MESTON, Alex. C., Licentiate R.I.B.A.; 26 Elmwood Road, Chiswick, LONDON, W.4.

1912. METSON, George, Captain, O.B.E., M.R.San.I., Licentiate R.I.B.A.; H.M. Office of Works, G.P.O. "North," St. Martin's-le-Grand, LONDON, E.C.1.

1914. MILLAR, John; 56 Crescent Lane, Clapham, LONDON, S.W.4.

1913. MINTER, F. A.; Ferry Works, Putney, LONDON, S.W.

1908. MISSO, W. J.; Assistant Engineer, P.W. Department, Morven, 15F Campbell Place, COLOMBO, Ceylon.

1910. MITCHELL, Fred. G.; River Place, City Road, MANCHESTER, Lancashire.

F. MITCHELL, H., Major, R.E.; Building Works Department, Royal Arsenal, Woolwich, LONDON, S.E.18.

1909. MITCHELL, Reginald St. John, B.Sc.; H.H. Nizam's Guaranteed State Railway, SECUNDERABAD, Deccan, India.

1908. MOIR, E. W., Sir, Bart., M.Inst.C.E.; 10 Victoria Street, LONDON, S.W.1.

1900. MONASH, John, Sir, K.C.B., M.C.E.(Melb.), M.Inst.C.E.; Collins House (3rd Floor), 360 Collins Street, MELBOURNE, Victoria, Australia.

1909. MONTGOMERY, R. N., B.A., B.A.I., Assoc.M.Inst.C.E.; Assistant Engineer, Pembroke U.D.C., PEMBROKE, Co. Dublin, Ireland.

1915. MOORSHEAD, Stephen, Junr.; Box 1980, JOHANNESBURG, S. Africa.

1909. MORANT, Francis H.; Hilton Road, NATAL, S.A.

1919. MORGAN, Adam, B.Sc.(Eng.), Assoc.M.Inst.C.E.; City Engineer's Office, Guildhall, LONDONDERRY, Ireland.

1909. MORGAN, F. E.; Acting Sanitary Engineer to Government of Madras, P.W. Department, CHEPAUK, Madras, India.

1908. MORLEY, John G., M.Inst.C.E., F.R.San.I.; Borough Engineer and Surveyor, Town Hall, West Ham, LONDON, E.

1909. MORRIS, Arthur Percy, B.Sc.; Headmaster, Government School of Engineering, Insein District, INSEIN, India.

ENROLLED.

1908. MOSS, Benjamin H., A.I.S.E.; Assistant Engineer, Norwood, SIMLA W., India.

F. MOULDING, Thomas, M.Inst.C.E.; City Engineer and Surveyor, EXETER, Devon.

1919. MOURANT, Charles O.; c/o The Indented Bar and Concrete Engineering Co., Ltd., Queen Anne's Chambers, Westminster, LONDON, S.W.1.

1910. MUIRHEAD, Thomas, B.Sc.(Eng.)Glasgow., Assoc.M.Inst.C.E., M.S.I.; c/o Messrs. Wm. Muirhead & Co., Ltd., 41 Parliament Street, Westminster, LONDON, S.W.1.

F. MUIRHEAD, W., M.Inst.C.E.; 41 Parliament Street, Westminster, LONDON, S.W.1.

1912. MUNDELL, J. E., A.R.I.B.A., F.S.I.; 21 William Street, Woolwich, LONDON, S.E.18.

1909. MUNNINGS, J. F., A.R.I.B.A.; Government Architect, Dorunda, Ranchi, BEHAR and ORISSA, India.

F. MUNRO, John; 11 Russel Gardens, GOLDER'S GREEN, Middlesex, N.W.4.

1909. MURRAY, Charles, Assoc.M.Inst.C.E.; Chief Engineer and Secretary, Public Works Department, Transvaal Colony, P.O. Box 439, PRETORIA, South Africa.

1909. MURRAY, Norman, Assoc.M.Inst.C.E., M.AberdeenAssoc.C.E.; Town Engineer's Office, WEYBURN, Sask., Canada.

1913. NAICKER, P. V. Manickram, B.E.(MadrasUniv.).

1913. NAPIER, W. S.; "Lawnswood," Huguenot Place, Wandsworth, LONDON, S.W.18.

1909. NEIGHBOUR, William F., F.S.I.; 7 and 8 Spenser Mansions, West Kensington, LONDON, W.14.

1909. NEILSON, W. H., B.A., B.A.I.(Dublin), M.Inst.C.E.; Chief Engineer, Port Trust, KARACHI, India.

1908. NEWCOMBE, Stewart F., Lieutenant-Colonel, R.E.; c/o Messrs. Cox & Co., 16 Charing Cross; also United Service Club, Pall Mall, LONDON, S.W.1.

1913. NEWSON, Charles, M.S.A.; 3 Grove Cottages, DITCHLING, near Hassocks, Sussex.

1909. NEWTON-HOWES, Robert William; Engineering Department (Open Lines), F.M.S. Railway, KUALA LUMPUR, F.M.S.

1909. NICHOLAS, Harry T.; Civil Engineer, P.W. Department, KUALA LUMPUR, Selangor, F.M.S.

1908. NICHOLSON, Stanley V.; Woodington, Palmer's Avenue, GRAYS, Essex.

1912. NICOL, L. R.; c/o Messrs. Armour & Co., SANTA CRUZ, Patagonia, S. America.

1910. NICOLL, James P., Assoc.N.Z.I.A.; P.W.D., Government Buildings, WELLINGTON, New Zealand.

1909. NORTH, H. N., Captain, R.E., Garrison Engineer; FORT SANDEMAN, Baluchistan, India.

1919. OLDERSHAW, George, M.J.I.E.; 13 Riversdale Road, Highbury, LONDON, N.5.

1909. OLDFIELD, H. Philip; "Glenlyon," HARROW-ON-THE-HILL, Middlesex.

ENROLLED.

1910. ORMSBY, P. H. K.; c/o Chief Engineer, S.A. Railway, JOHANNESBURG, South Africa.
1912. ORR, Robert, A.R.I.B.A., P.A.S.I.
1909. ORRELL, A. C. V.; 16 Willowdene Terrace, Woodlands Road, MIDDLESBROUGH, Yorkshire.
1908. OWEN Richard H.; 1 Gresham Buildings, Basinghall Street, LONDON, E.C.2.
1910. OWEN, Segar, F.R.I.B.A.; Cairo Street Chambers, WARRINGTON, Lancashire
1913. OWENS, John S., Assoc.M.Inst.C.E., F.R.G.S., F.G.S.; 47
V-P.,C. Victoria Street, Westminster, LONDON, S.W.1.

1911. PACKER, L. H.; "Tiverton," Station Road, COATDYKE, Coatbridge, Scotland.
1908. PALLISER, W. A., P.A.S.I.
F. PALMER, Phillip H., M.Inst.C.E.; Borough Engineer, Town Hall, HASTINGS, Sussex.
1909. PALMER, W. E. K., A.R.I.B.A., F.S.I.; 7 Duke Street, Adelphi, LONDON, W.C.2.
1912. PALSER, Edwin, Licentiate R.I.B.A.; 9 John Street, Adelphi, LONDON, W.C.2.
1909. PARFITT, E. W.; Resident Engineer, Great Western of Brazil Railway, Caixa 114, PERNAMBUCO, Brazil, S. America.
1912. PARHAM, John, M.R.San.I.; Building Inspector, Enfield U.D.C., Public Offices, ENFIELD, Middlesex.
1915. PARKER, Frederick, F.R.Soc.Arts, M.Q.S.A.; The Square, BOSTON, Lincolnshire.
1909. PARR, S. George, F.S.I.; 35 New Broad Street, LONDON, E.C.2.
1916. PAWLEY, Frank L., Major, R.G.A., Assoc.M.Inst.C.E.; Oak Tree House, PRESTON, near Hull, Yorkshire.
1908. PEARSON, E. E., F.R.G.S.; 10 Victoria Street, LONDON, S.W.1.
1911. PENTY, Harold F.; c/o Messrs. Charles Heathcote & Sons, 110 Cannon Street, LONDON, E.C.4.
1909. PERCY, W. Herbert; 34 De Vere Gardens, Kensington, LONDON, W.8.
1909. PERKINS, E. J.; PORT SWETTENHAM, F.M.S.
1908. PERKINS, W. G.; District Surveyor for Holborn, 6 Raymond Buildings, Gray's Inn, LONDON, W.C.1.
1909. PERRIN, A. T., A.M.I.Mech.E.; P.O. Box 2212, MONTREAL, Canada.
1908. PERROTT, S. W., Professor, M.A.I.(Dublin), M.Inst.C.E.; Dept. of Civil Engineering, The University, LIVERPOOL, Lancashire.
1909. PERRY, William R. V. P., B.A., M.A.I.(Dublin), M.Inst.C.E.; District Engineer, Great Southern and Western Railway, LIMERICK, Ireland.
1909. PETAVEL, J. E., M.Sc., F.R.S., Assoc.M.Inst.C.E.; Beyer Professor of Engineering and Director of the Whitworth Laboratory, The University, MANCHESTER, Lancashire.
1910. PETRIE, James, Major, O.B.E.; London, Brighton & South
C. Coast Railway, District Engineer's Office, EAST CROYDON, Surrey.
1908. PETTERS, J. M'F.; Executive Engineer, Public Works Department, RANGOON, Burma, India.

ENROLLED.

1909. PHILLIPS, E. A. W., M.Inst.C.E.; Rawdon House, 4 Aymer Road, HOVE, Sussex.

1919. PICKERING, Wilfred J., Lieutenant, R.E.: Chief Assistant Surveyor of Highways, Epsom R.D.C., 53 Church Road, EPSOM, Surrey.

1909. PIERCY, James Edward; Earnsfoot, Robinson Road, HONG KONG, China.

1908. PIGGFORD, Jonathan, M.I.Min.E.; c/o Messrs. Crompton & Evans, The Bank, MANSFIELD, Nottinghamshire.

1908. PIKE, Albert T. J.; 10 Kiukiang Road, SHANGHAI, China.

1912. PIKE, J. Percy, P.A.S.I., M.I.S.E.; 331 Croxted Road, Herne Hill, LONDON, S.E.24.

1909. PILLSBURY, J. H., S.B.; Assistant Harbour Engineer, Grand Trunk Pacific Railway, PRINCE RUPERT, B.C., Canada.

1913. PIMM, G. B. R., Second Lieutenant, R.E., Assoc.M.Inst.C.E.; 18 Morton Road, EXMOUTH, Devon.

1912. PITMAN, A. J.

1912. PITT, A. O.; c/o Messrs. Hansford & Hansford, 46 Pine Street, DURBAN, South Africa.

1913. PLAISTER, J. F.; Crouch House, SEAFORD, Sussex.

1919. PLATT, S. S., M.Inst.C.E.; Cartrefle, Wynnstay Road, OLD COLWYN, N. Wales.

1908. PLYMOUTH, The Right Hon. the Earl of, P.C., G.B.E., C.B.; P-P. 54 Mount Street, LONDON, W.1.

1908. POATE, W. J.; 88 Colmore Row, BIRMINGHAM, Warwickshire.

1908. PORTEOUS, Norman, M.C., Assoc.M.Inst.C.E.; 34 Castle Street, EDINBURGH, Scotland.

1909. POULDEN, G. E. L., Captain, S.R.E.S., Assoc.M.Inst.C.E., M.I.Mun.&Co.E.; 11 The Warren, ALDERSHOT, Hampshire.

1908. POWELL, Sidney J., Assoc.M.Inst.C.E.: Shanghai Club, SHANGHAI, China.

1908. PRICE, A. B., Assoc.M.Inst.C.E.; The Modern Construction Co., Ltd., South Street, Scotstoun, GLASGOW, Scotland.

1913. PRIESTLEY, C. F.; 7 Victoria Road, Upper Norwood, LONDON, S.E.19.

1909. PROVIS, C. H.; c/o Dean Stone Co., Ltd., Exmouth Road, DEVONPORT, Devon.

1908. PULFORD, W. J., Lieutenant, M.S.A.: County Land Agent, County Buildings, SHREWSBURY.

1908. PUPLETT, Henry, M.S.E.; 47 Victoria Street, Westminster LONDON, S.W.1.

1909. PURCELL, J. E., Assoc.M.Inst.C.E.: Lismore, Knocknacree Road, DALKEY, Ireland.

F.C. PURTON, Frederick, F.S.E.; York Mansion, York Street, Westminster, LONDON, S.W.1.

1912. RADCLIFFE, Frank; Alpine Villa, Mountjoy Road, HUDDERSFIELD, Yorkshire.

1908. RAINE, George, M. Iron & Steel Inst.; Pilgrim House, NEWCASTLE-ON-TYNE, Northumberland.

1913. RANDALL, G. Y., Holmesdale, King Edward Avenue, BROADSTAIRS, Thanet, Kent.

ENROLLED.

1918. RATCLIFF, William W., Captain, R.E., Assoc.M.Inst.C.E., F.G.S., M.I.Mun.&Co.E.; The Willows, WEST DRAYTON, Middlesex.

1909. RATTRAY, D. C., M.Inst.C.E.; Chief Engineer, Lancashire & Yorkshire Railway, MANCHESTER, Lancashire.

1913. RAU, R. Vittal, M.J.I.E.; c/o The Sanitary Engineer, City Improvements Board, HYDERABAD, Deccan, India.

1910. REED, Charles A.; c/o Trussed Concrete Steel Co., Circular Quay West, SYDNEY, N.S.W., Australia.

1908. REED, Gerald H.; Wembury, LAUNCESTON, Cornwall.

1911. REES, W. D., Colonel V.D., R.E., M.Iron&SteelInst.; 16 Clifton Gardens, LONDON, W.9.

1909. REID, Robert; Harold Road, Lynn Valley, NORTH VANCOUVER, B.C., Canada.

1909. REMFREY, D. H., B.E.(Calcutta), Assoc.M.Inst.C.E.; District Engineer, Bhaga, Bengal-Nagpur Railway, MANBHUM, Behar and Orissa, India.

1915. REMY, L.; Officina é Escripterio Technico, Rua Guanabara No. 47, RIO DE JANEIRO, South America.

1908. RENNIE, John D., Assoc.M.Inst.C.E.; c/o Messrs. J. G. White & Co., Ltd., Casilla J, GUAYAQUIL, Ecuador, S. America.

1911. REYNOLDS, B. O.

1919. REYNOLDS, Frank S., M.S.A.; 27 Vakhovitch, HANKOW, China.

1916. RICE, Cyril.

1919. RICHARDS, Charles V., B.Sc., Assoc.M.Inst.C.E., Assoc.M.Inst.Mun.&Co.E.; 27 Needwood Street, BURTON-ON-TRENT, Staffordshire.

F. RICHARDS, H. W., Principal of London County Council School of Building, "Brookside," Beverley Road, Barnes, LONDON, S.W.13.

1616. RICHARDS, Walter, F.S.I.

1908. RICKIE, James H., B.E.(Liverpool); c/o The Agent, Burma Railways Co., Ltd., RANGOON, Burma, India.

1911. RIDER, James, M.Iron&SteelInst.; Cleveland Wire Mills, MIDDLESBROUGH, Yorkshire.

1911. RIDLEY, M. Noel, M.Inst.C.E.; 6 Clova Road, FOREST GATE, Essex, E.7.

1909. RIDLEY, P. E., F.S.I., A.I.E.E.; "Abinger," Burcott Road, PURLEY, Surrey.

1908. RIGBY, John S., F.C.S.; 26 Bagot Street, LIVERPOOL, Lancashire.

1912. RITCHIE, G. T., B.Sc.(Birmingham), Assoc.M.Inst.C.E.; P.O. Box No. 1, LADISMITH, C.P., S. Africa.

1908. RIVETT-CARNAC, S. G., Major, R.E.; c/o Messrs. Cox & Co., 16 Charing Cross, LONDON, S.W.1.

1908. ROBERTS, Alfred H.; Harbour and Dock Office, LEITH, Scotland.

1912. ROBERTS, George S.; c/o Messrs. A. Roberts & Co., 74 Earl's Court Road, Kensington, LONDON, W.8.

1913. ROBERTS, Sydney S.; Hallgarth, St. Margaret's Road, ST. MARGARET'S-ON-THAMES, Twickenham, Middlesex.

1910. ROBERTSON, D. W.; 20 Gilmour Road, EDINBURGH, Scotland.

1908. ROBERTSON, Thomas; Building Inspector, Contracts Branch, H.M. Office of Works, Westminster, LONDON, S.W.1.

ENROLLED.

1908. ROBINSON, Hector St. G.; "Harlow," Hedge Lane, PALMER'S GREEN, Middlesex, N.13.
1908. ROBINSON, Norman.
1911. ROBINSON, S. G., M.I.Mech.E.
1911. ROBINSON, Wilfrid H., M.S.A.; Buildings Department, Sessions House, MAIDSTONE, Kent.
1909. RODERICK, T. J.; 322 Calle Guanahani, BUENOS AIRES, Argentine, S. America.
1914. RODRIGUEZ, Isaac J., Engineer; Box 244, VALPARAISO, Chile, S. America.
1909. ROEBUCK, John Herbert; Berridale, STROMNESS, Orkney, Scotland.
F. ROGERS, H. S., Major, R.E.; Surveyor of Prisons, Home Office, Whitehall, LONDON, S.W.1.
1909. ROSE, John G., 38 West Sunniside, SUNDERLAND, Durham.
1908. ROSENTHAL, Frederick M. B., Assoc.M.Inst.C.E.; Acting District Engineer, H.H. Nizam's Guaranteed State Railway Co., SECUNDERABAD, Deccan, India.
F. ROSEVEARE, Leslie, Captain, R.E., M.Inst.C.E.; Borough Engineer and Surveyor, SOUTH SHIELDS, Durham.
F. ROSS, Alexander, M.Inst.C.E.; Kingslea, 36 Fellows Road, South Hampstead, LONDON, N.W.3.
1909. ROTHERY, W. B., M.I.Mech.E.; Inspecting Engineer, Hazelmere, SOUTHPORT, Lancashire.
1919. ROTHWELL, William E.; 13 Hornby Road, Old Trafford, MANCHESTER, Lancashire.
1909. ROWNEY, G. A. H., B.A., B.E.(Royal), Assoc.M.Inst.C.E.; Wollondilly Shire, THE OAKS, N.S.W., Australia.
1909. ROYDS, Edward A.
1912. RUDMAN, L. S.; Chiltern, Hale Lane, MILL HILL, Middlesex, N.W.7.
F. RUGG, Lewis H., Assoc.M.Inst.C.E.
1909. RUSSELL, Robert, J.P.; Whitestripe House, NEWMAINES, Lanarkshire, Scotland.
1908. RYVES, Reginald A., Assoc.M.Inst.C.E., M.Cons.E.; Damory Cottage, WALTON-ON-THE-HILL, Surrey.

1912. SAGE, A. R.; L.C.C. School of Building, Ferndale Road,
C. Brixton, LONDON, S.W.
1908. SAISE, Alfred J., J.P.; Ventnor House, Fishponds, BRISTOL, Gloucestershire.
1910. SAISE, Walter, Captain, R.E.; Ventnor House, Fishponds, BRISTOL, Gloucestershire.
1908. SALMON, H.; The Expanded Metal Co., Ltd., Stranton Works, WEST HARTLEPOOL, Durham.
1911. SANDS, Hubert C., Captain, R.A.M.C.(T.), F.S.I.; "Amhurst," Guibal Road, Lee, LONDON, S.E.12.
1909. SANER, J. A., Colonel, M.Inst.C.E.; Engineer's Office, Weaver Navigation, NORTHWICH, Cheshire.
1919. SARGEANT, Edward F., Assoc.M.Inst.C.E., M.I.Mech.E.; 83 Waterloo Crescent, NOTTINGHAM.
1913. SAVAGE, Arthur J., Lieut.-Col., D.S.O., R.E.; c/o Messrs. Cox & Co., 16 Charing Cross, LONDON, S.W.1.
1911. SAWYER, Harold S., Captain, A.R.I.B.A.; "Bushy," LOOSE, near Maidstone, Kent.

ENROLLED.

1909. SCHWABE, G. A. E., Assoc. Manchester Soc. Archts.; West Hill Cottage, BRAUNTON, R.S.O., Devon.

F.C. SCOTT, A. Alban H., M.S.A.; 13 Old Square, Lincoln's Inn, LONDON, W.C.2.

1913. SCOTT, Archibald, A.R.I.B.A.; H.M. Office of Works, Storey's Gate, Westminster, LONDON, S.W.1.

1908. SCOTT, C. V. G.; c/o Messrs. King, King & Co., Agents and Bankers, BOMBAY, India.

1908. SCOTT, Charles W., B.A.I.(Dublin), Assoc.M.Inst.C.E.; Engineer to Commissioners of Irish Lights, Irish Lights Office, DUBLIN, Ireland.

1913. SEARCHFIELD, Ernest J.; Clerk of Works, H.M. Office of Works, New Public Offices Extension, Westminster, LONDON, S.W.1.

F.P. SEARLES-WOOD, H. D., F.R.I.B.A.; 157 Wool Exchange, Coleman Street, LONDON, E.C.2.

1913. SELBY, Albert, 20 Rosslyn Road, Barking, LONDON, E.

1908. SEWELL, William, M.Inst.C.E.; 15 North Bridge Street, SUNDERLAND, Durham.

1913. SHADBOLT, Blunden, Licentiate R.I.B.A.; Victoria Road, HORLEY, Surrey.

1909. SHADBOLT, Leslie Garret; "Rylstone," HAREFIELD, near Uxbridge, Middlesex.

1909. SHARP, Joseph G., Lieut., R.A., Assoc.M.Inst.C.E.; "Banklands," WORKINGTON, Cumberland.

1919. SHARPE, Gerald, A.M.I.Mech.E.; Rosslyn, South Road, CHORLEY WOOD, Hertfordshire.

1908. SHAW, W. C., Assoc.M.Inst.C.E.; Elnor House, Whaley Bridge, STOCKPORT, Cheshire.

1913. SHELBOURNE, H. J., Major, R.E.; The Hall, SOUTHWICK, near Brighton, Sussex.

1918. SHELF, Arthur W. C.; Mount Pleasant, PADDOCK WOOD, Kent.

1919. SHEPPARD, William G., B.A.(Cantab); 189 Croxted Road, West Dulwich, LONDON, S.E.21.

1909. SHERRING, Arthur Edwin; 1, Dunbar Road, FOREST GATE, Essex, E.7.

1913. SHERWOOD, Herbert E., M.S.A.; Assistant Engineer, c/o Municipality, PRETORIA, S. Africa.

1909. SHIMOMURA, Naoyoshi; c/o Maintenance of Way Office of the Imperial Government Railways, NUTSU YECHIGO, Japan.

1913. SHINER, Lawrence A. D., A.R.I.B.A.; 7 Adam Street, Adelphi, LONDON, W.C.2.

1910. SHIPWRIGHT, William G., P.A.S.I.; 218 Wellmeadow Road, Catford, LONDON, S.E.6.

1908. SHORE, T. B., M.S.E.; c/o Sir William Arrol & Co., Ltd.,
C. GLASGOW, Scotland.

1915. SIACCI, Giacinto, Cav., M.Soc.C.E.d'Egypt(Cairo); AUCKLAND, N.Z.

F. SICKMAN, J. F.

1910. SILVER, S. T.; Woodward Street, WELLINGTON, New Zealand.

1914. SIMCO, Percy H.; Brambledene, Brambledown Road, WALLINGTON, Surrey.

ENROLLED.

1909. SIMPSON, Edmund, M. Manchester Assn. Engrs.; Cranford, ALDERLEY EDGE, Cheshire.
1908. SIMPSON, H. Leigh; 44 Plymouth Road, PENARTH, Wales.
1910. SIMPSON, James W.; Chief Engineer's Office, M. & S.M. Rly. Co., Ltd., ROYAPURAM, Madras, India.
1908. SIMPSON, William, M.Inst.C.E.; Engineer to River Wear Commission (Port of Sunderland), Commission's Offices, SUNDERLAND, Durham.
1909. SINCLAIR, R. N.; Engineer's Department, London & South-Western Railway, SOUTHAMPTON DOCKS, Hampshire.
1909. SISSON, Norman, M.Inst.C.E.; c/o Messrs. Hughes & Lancaster, 16 Victoria Street, Westminster, LONDON, S.W.1.
1913. SMALL, J. Allan.
1910. SMITH, J. Landreth; Public Works Department, Kingstown, ST. VINCENT, B.W.I.
1911. SMITH, J. Osborne, F.R.I.B.A., F.R.San.I.; 197 Victoria Street, Westminster, LONDON, S.W.1.
1909. SMITH, P. Rider, A.R.I.B.A.; Burlevane, Waxwell Lane, PINNER, Middlesex.
1908. SMITH, Samuel F., M.Inst.C.E.; 200 Gray's Inn Road, LONDON, W.C.1.
1909. SMITH, Sydney; Engineer, Mains of Foulis, DUNDEE, Scotland.
1908. SMITH, Thomas R., Assoc.M.Inst.C.E.; Engineer and Surveyor to U.D.C., KETTERING, Northamptonshire.
1910. SNELL, Albion T., M.Inst.C.E., M.I.E.E.; Suffolk House, 5 Laurence Pountney Hill, Cannon Street, LONDON, E.C.4.
1908. SNOWDEN, Fred, M.Inst.C.E.; Acting Chief Engineer, Manila Railway Co., MANILA, Philippine Islands.
1909. SOLLY, J. B. Travers, Assoc.M.Inst.C.E.; c/o The Guinea Traders' Association (1915), Ltd., CAPE COAST, West Africa.
1908. SOMERVILLE, D. G.; 120 Victoria Street, LONDON, S.W.1.
1908. SPACKMAN, Charles, F.I.C.; Rosehaugh, CLITHEROE, Lancashire.
1909. SPEAKER, G. R.; 29 Mincing Lane, LONDON, E.C.3.
1909. SPEIGHT, Leonard J.; 16 Belgrave Road, WANSTEAD, Essex.
1908. SPENCER, H. E.; 111 Albert Bridge Road, Battersea, LONDON, S.W.11.
1908. SPURR, Frank W.; City Engineer and Surveyor, Guildhall, YORK.
1908. STANBURY, W. H., Major, S.R.E.S., A.R.I.B.A., M.R.San.I.; Royal Engineers' Office, TIDWORTH BARRACKS, Hants.
1908. STANGER, R. H. H., Assoc.M.Inst.C.E.; Broadway House, 26-28 Tothill Street, Westminster, LONDON, S.W.1.
1908. STANLEY, E. G., Assoc.M.Inst.C.E.; c/o Messrs. H. S. King & Co., 9 Pall Mall, LONDON, S.W.1.
1909. STANSFELD, Alfred W., M.Inst.C.E.; General Engineer and Manager, Leeds and Liverpool Canal Co., Pall Mall, LIVERPOOL, Lancashire.
1917. STEDMAN, Alfred G.; Cleveland Place, Farncombe Hill, GODALMING, Surrey.
1910. STEINBERG, Herbert E., Lieut., Assoc.M.Inst.C.E.; c/o Considère Construction Co., Ltd., 5 Victoria Street, Westminster, LONDON, S.W.1.
1914. STEVEN-JENNINGS, C. A., M.Soc.Arch.S.A.

ENROLLED.

1909. STEVENS, Percival, Assoc.M.Inst.C.E.; Assistant Director, Public Works Department, Port of Spain, TRINIDAD, West Indies.

1909. STEWART, A. M., Assoc.M.Inst.C.E.; Depart. Via y Obras, Ferro Carril Oeste, BUENOS AIRES, Argentine, S. America.

1912. STEWART, J. Vaughan, Junr.; Cairnsmuir, LLANELLY, Carmarthen, Wales.

1909. STEWART, Percy M.; 4 Templewood Avenue, Hampstead, LONDON, N.W.3.

1909. STEWART, William J.; 42 Albemarle Street, LONDON, W.1.

1908. STODDART, C., Assoc.M.Inst.C.E.; 80 Beresford Road, North End, PORTSMOUTH, Hampshire.

1908. STOKES, A. P.; District Surveyor for Norwood, 365 Norwood Road, LONDON, S.E.27.

1909. STOKES, Geo. W.; The Cottage, Swann Lane, CHEADLE HULME, Cheshire.

1908. STOKOE, Edward R., Assoc.M.Inst.C.E.; State Engineer, SELANGOR, F.M.S.

1912. STONIER, G. Mannering; 144 St. Vincent Street, GLASGOW, Scotland.

1909. STORR, F., M. Iron and Steel Inst.; 21 Egerton Street, WREXHAM, N. Wales.

1912. STREADWICK, J. E.; 1st Class Superintendent, Public Works Office, KINGSTON, Jamaica, B.W.I.

1909. STUART, J. D., Assoc.M.Inst.C.E.; Executive Engineer, Public Works Department, c/o Messrs. A. Scott & Co., RANGOON, Burma, India.

1909. SUFFIELD, Frank W.; 57 Colmore Row, BIRMINGHAM, Warwickshire.

F. SURTEES, Richard T.; "Hawthorn Bank," NEWTON-LE-WILLOWS, Lancashire.

1913. SUTHERLAND, D. S., M.R.San.I.; Southgate U.D.C., Council Offices, PALMER'S GREEN, Middlesex, N.13.

1912. SUTHERLAND, Ian M., M.C.E.(Melbourne Univ.); Novar, Dandenong, VICTORIA, Australia.

1913. SVENDSEN, Ole., M.I.C.E.(Denmark); "Rockwell," Colney Hatch Lane, Muswell Hill, LONDON, N.10.

1908. SWAN, A. D., M.Inst.C.E., M.I.M.E., M.Can.Soc.C.E.; 10 Phillips Place, MONTREAL, Canada.

1909. SWIFT, J. Arthur; KLANG, Federated Malay States.

1909. SYKES, C. F., F.C.H., Assoc.M.Inst.C.E.; Redbarn Hill, FINCHAMPSTEAD, Wellington College Station, Berkshire.

F. TANNER, Sir Henry, C.B., I.S.O., F.R.I.B.A.; Carlton
P.P. Chambers, 12, Regent Street, LONDON, S.W.1.

1908. TANNER, Henry, F.R.I.B.A.; 12 Regent Street, LONDON, S.W.1

1913. TAYLOR, B., M. Salford Eng. Assn.; c/o Reinforced Concrete Department, Messrs. Richard Johnson, Clapham & Morris, Ltd., Lever Street, MANCHESTER, Lancashire.

1909. TAYLOR, David.

1908. TAYLOR, Francis R., M.R.San.I.; 12 Pleydell Avenue, Stamford Brook, LONDON, W.6.

1912. TAYLOR, J. E.

ENROLLED.

1908. TAYLOR, Walter R.; Woodbank, Clement Road, MARPLE BRIDGE, Derbyshire.

1910. TEBBUTT, Louis; 4 Tension Avenue, CAMBRIDGE.

1909. THEOBALD, John M., F.S.I.; 110 Great Russell Street, Bedford Square, LONDON, W.C.1.

1912. THOMAS, Wm. F. Lauric, M.R.San.I.; Town Superintendent, Town Hall, GEORGETOWN, Demerara, British Guiana.

1909. THOMPSON, H. J., A.K.C., M.Inst.C.E.; "Tregarthen," Garland's Road, LEATHERHEAD, Surrey.

1908. THOMPSON, James, B.E.(Queen's), M.Inst.C.E.; Engineer-in-Chief for Western Australia, P.W.D., PERTH, W.A.

1909. THOMPSON, Michael S., Assoc.M.Inst.C.E.; SALAHIB, via Biela, Lower Egypt.

1911. THOMPSON, Richard S., Assoc.M.Inst.C.E.; Engineer to Patea Harbour Board, Engineer's Office, PATEA, New Zealand. (Life Member.)

F. THOMSON, James; City Engineer and City Architect of Dundee, 91 Commercial Street, DUNDEE, Scotland.

1908. THOMSON, John; Engineer's Office, G.E. Railway, Liverpool Street Station, LONDON, E.C.2.

1910. THORNE, Philip H.; 21 Crouch Hall Road, Crouch End, LONDON, N.8.

1912. THORNELEY, Walter C.

1909. THORNHILL, W. E., Captain (T.), M.C., Assoc.M.Inst.C.E.; Divisional Engineer's Office, Permanent Way Department, Crewe Station, CREWE, Cheshire.

1908. C. TINGLE, Henry J., M.Inst.C.E.; 21 Queen Anne's Gate, Westminster, LONDON, S.W.1.

1911. TINSLAY, Thos. P., P.A.S.I.; 53 Bradbourne Street, Parson's Green, LONDON, S.W.6.

1909. TODD, John S., Assoc.M.Inst.C.E.; St. Brook, WOODFORD BRIDGE, Essex.

1909. TOLHURST, P. W., Assoc.M.Inst.C.E.; c/o Capital & Counties Bank, Ltd., GRAVESEND, Kent.

1916. TOMLINSON, Alfred, M.Sc.(Manchester and West Australia), Assoc.M.Inst.C.E.; Acting Professor of Mining and Engineering, University of Western Australia, PERTH, W.A.

1912. TONKIN, Wilfred W., Licentiate R.I.B.A.; Public Works Department, POTCHEFSTROOM, Transvaal, South Africa.

1917. TOOGOOD, Henry F.; 11 Grey Street, WELLINGTON, New Zealand.

1908. TOPHAM, W. H., Assoc.Inst.C.E.; 11 Great George Street, Westminster, LONDON, S.W.1.

1912. TREACHER, F. J.; Albion Villa, Lower Wyche, MALVERN, Worcestershire.

1909. TRECHMANN, A. O., F.C.S.; c/o Otto Trechmann, Ltd., Warren Cement Works, WEST HARTLEPOOL, Durham.

1913. TRENTHAM, G. Percy; Winchester House, Victoria Square, BIRMINGHAM, Warwickshire.

1910. TRIGGS, B. G., M.S.A.; RUTLAM, C. India.

1909. TRIMMER, G. W. Arthur, A.M.I.Mech.E.; c/o Messrs. Topham, Jones & Railton, SINGAPORE, Straits Settlements.

ENROLLED.

1900. TROTMAN, George, F.I.San.E., M.S.A.; 32 Camberwell Grove, LONDON, S.E.5.

1913. TUCKER, Walter S., A.R.I.B.A.; Architect's Department, London County Council, New County Hall, LONDON, S.E.1.

1912. TURNER, Hamilton H., M.Q.S.A.; 48 Broadway, Westminster, LONDON, S.W.1.

1908. TURRIFF, A. A., M.R.San.I., Burgh Engineer, ELGIN, Scotland.

1909. TWEEN, Charles N., M.Inst.C.E.; Engineer and Manager to Lee Conservancy Board, ENFIELD LOCK, Middlesex.

1918. TYLER, James, Assoc.M.N.Z.Soc.C.E.; Assistant City Engineer, Town Hall, AUCKLAND, N.Z.

1919. TYTE, Gilbert G. L., A.R.I.B.A.; 26 St. George's Square, Regent's Park, LONDON, N.W.1.

1909. ULDALL, S. V. A.; Green Island, HONG KONG, China.

1909. UPCHER, Cecil; 6 Upper King Street, NORWICH, Norfolk.

1918. VANNER, William A.; 1 Park Place, HAMPTON HILL, Middlesex.

1909. VANSTONE, F. W.; 6 Torbay Road, PAIGNTON, Devon.

1908. VAUCLAIN, S. M., D.Sc., A.S.M.E.; 500 N. Broad Street, PHILADELPHIA, U.S.A.

F.C. VAWDREY, R. W., B.A.(Cantab.), Assoc.M.Inst.C.E.; c/o The Indented Bar & Concrete Engineering Co., Ltd., Queen Anne's Chambers, Westminster, LONDON, S.W.1.

1909. VEALE, Ernest W.; Surveyor, Southern District, Farnham R.D.C., Surveyor's Office, FRENSHAM, Surrey.

1909. VYALL, F. S.; "Avondale," Halpin Road, RANGOON, Lower Burma, India.

1909. WADDELL, William, M.Inst.C.E.; General Manager to Barry Railway Co., BARRY DOCKS, S. Wales.

1913. WADE, Francis R., M.B.E., M.I.Mech.E., M.I.A.E.; 95 Colmore Row, BIRMINGHAM, Warwickshire.

1908. WAGER, J., A.R.I.B.A.; 17 Elsham Road, West Kensington, LONDON, W.14.

1912. WALDRAM, Percy J., F.S.I., Licentiate R.I.B.A.; Robins Croft, Second Avenue, HENDON, Middlesex, N.W.4.

1908. WALDRON, Frank W.; MOSSEL BAY, Cape Colony, S.A.

1911. WALKER, J. B., Captain, A.M.I.Mech.E.; c o T. J. Walker, Esq., 11 Broomwater, TEDDINGTON, Middlesex.

1909. WALKER, Robert; P.O. Box 351, BULAWAYO, Rhodesia, South Africa.

1908. WALKER, Robert R.; 5 East India Avenue, LONDON, E.C.3.

1911. WALKER, W. H.; c/o Winget, Ltd., 31 Rue de Mogador, PARIS, France.

1910. WALLACE, W. K., Assoc.M.Inst.C.E., M.S.E., M.Am.C.I.; Northern Counties Committee, Engineer's Office, Midland Railway, BELFAST, Ireland.

1909. WALTON, H., M.Sc.(Victoria); Executive Engineer, FORT DUFFERIN, Mandalay, Burma, India.

ENROLLED.

1909. WARD, E. T., Assoc.M.Inst.C.E.; 6 Genesta Road, WESTCLIFF-ON-SEA, Essex.

1919. WARD, Frederick J.; 210 Well Hall Road, Eltham, LONDON, S.E.9.

1914. WARDEN, J. F.; 117 Rosendale Road, West Dulwich, LONDON, S.E.21.

1909. WARDLEY, J. H., Assoc.M.Inst.C.E.; "Fairview," CHIGWELL ROW, Essex.

1908. WARE, Edmund, M.Q.S.A.; 43 Imperial Buildings, Exchange Street East, LIVERPOOL, Lancashire.

1917. WATKINS, Henry H.; c/o Box 208, G.P.O., AUCKLAND, N.Z.

1909. WATKINS, S., Assoc.M.Inst.C.E.; Ottoman Railway Co., SMYRNA, Turkey in Asia.

1919. WATKINSON, Harold E., P.A.S.I.; Grafton, 9 Hemdean Rise, CAVERSHAM, near Reading, Berkshire.

1913. WATSON, Fredk. P.

1909. WATSON, J. W., Assoc.M.Inst.C.E.; Manager, British North Borneo Railway, JESSELTON, B.N.B.

1908. WATSON, T. A., Assoc.M.Inst.C.E.; 4 Haydn Avenue, C. PURLEY, Surrey.

1909. WATTS, R. W.; Assistant Engineer, North-Western Railway, RAWAL PINDI, India.

1908. WEBB, Maurice E., Major, M.C., D.S.O., M.A.(Cantab); 19 Queen Anne's Gate, LONDON, S.W.1.

1908. WEBBER, W. H., F.S.I.; 33 Furnival Street, Holborn, LONDON, E.C.4.

F. WELLS, E. P., J.P.; 51 New St. John's Road, ST. HELIERS,
P.-P. Jersey, C.I.

1915. WELLS, William; Waterworks Engineer, c/o Ferro Carril de Antofagasta à Bolivia, ANTOFAGASTA, Chile, S. America.

F. WENTWORTH-SHEILDS, F. E., M.Inst.C.E.; Dock En-
P-P. gineer, L. & S.W. Railway, SOUTHAMPTON DOCKS, Hampshire.

1911. WEST, W. E., M.I.Mech.E., 13 Victoria Street, Westminster, LONDON, S.W.1.

1912. WHARTON, E. Vernon; Public Works Department, PORT OF SPAIN, Trinidad, B.W.I.

1909. WHEATLEY, H. L., Assoc.M.Inst.C.E.; P.O. Box 531, RIO DE JANEIRO, Brazil, S. America.

1909. WHITAKER, James, Assoc.M.Inst.C.E.; 3 Cooper Street, MANCHESTER, Lancashire.

1909. WHITEHOUSE, George H., M.Inst.C.E.; South African Railways, JOHANNESBURG, Transvaal, S.A.

1913. WHYTE, John M., Assoc.M.Inst.C.E.; 145 Jerningham Road, New Cross, LONDON, S.E.14.

1908. WILLANS, T. B., M.Sc.(Victoria), Assoc.M.Inst.C.E.; Great Central Railway Engineer's Office, Marylebone Station, LONDON, N.W.1.

1909. WILLIAMS, Arthur E., Assoc.M.Inst.C.E.; DAGENHAM DOCK, Essex.

1908. WILLIAMS, Llewellyn E., A.R.I.B.A.; Box 666, G.P.O., WELLINGTON, N.Z.

1915. WILLIAMS, Percy, A.M.I.Mech.E.; Min Afon, Cressington Park, LIVERPOOL, Lancashire.

1909. WILLIAMSON, James.

ENROLLED.

1909. WILLMOTT, C. Spencer; 10 Highview Road, WEST EALING, Middlesex, W.13.

1909. WILSON, Charles C. P.; 1433 Sturt Street, BALLARAT, Victoria, Australia.

1908. WILSON, J. F., M.Inst.C.E.; Standard Bank of South Africa, 10 Clement's Lane, LONDON, E.C.4.

F. WINN, J., Lieut.-Col., R.E.; Whytcleafe, The Grange, WIMBLEDON, Surrey, S.W.19.

F. WISE, W. K.; 20 Binfield Road, Clapham, LONDON, S.W.4.

1909. WOOD, Gerald G.; c/o Messrs. Leigh & Orange, HONG KONG, China.

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